MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXIX. *February* 12, 1869. No. 4.

Admiral MANNERS, President, in the Chair.

W. J. H. Beechey, Esq., Westbury-on-Severn;
Jas. Robert Jones, Esq., Aberdeen;
John Lee, Esq., St, Peter's Chambers, Cornhill;
Dr. Geo. Royston Pigott, 2 Lansdowne Crescent, Notting Hill; and
T. Ryle, Esq., Eastbourne,

were balloted for and duly elected Fellows of the Society.

Report of the Council to the Forty-ninth General Meeting of the Society.

Progress and present state of the Society:—

	Compounders.	Annual Contributors.	Non-residents.	Patroness, and Honorary.	Total Fellows.	Associates.	Grand Total.
December 31, 1867	179	286	13	4	482	46	528
Since elected ...	5	18	...	...	...	...	...
Deceased	−5	−5	−1	−1	...	−1	...
Removals	+3	−3	...	...	...	...	...
Dec. 31, 1868 ...	182	296	12	3	493	45	538

Mr. Whitbread's Account as Treasurer of the Royal Astronomical Society, from January 1 to December 31, 1868:—

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance of last year's account				117	18	9
By Dividend on £2800 Consols	40	19	0			
By ditto on £5000 New 3 per Cents ...	73	2	6			
By ditto on £2800 Consols	40	19	0			
By ditto on £5000 New 3 per Cents ...	73	2	6			
				228	3	0
On account of arrears of contributions ...	141	10	0			
182 annual contributions	382	4	0			
22 admission-fees	46	4	0			
17 first years' contributions	26	5	0			
				596	3	0
7 compositions				144	18	0
Sale of publications:—						
At the Rooms of the Society	79	8	0			
By Messrs. Williams and Norgate, Publishers	42	9	0			
				121	17	0
				£1208	19	9

EXPENDITURE.

	£	s.	d.	£	s.	d.
Salaries :—						
Editor of Publications	60	0	0			
Assistant Secretary	130	0	0			
Commission on Collecting	33	16	0			
				223	16	0
Taxes :—						
Land and Assessed	6	11	0			
Income	2	1	8			
Poor Rate	4	15	10			
Other Parish Rates	2	18	4			
				16	6	10
Bills :—						
Strangeways and Walden, printers ...	173	4	0			
Rumfitt, bookbinder	30	3	2			
Basire, engraver	16	7	6			
Malby, lithographer	5	5	0			
Harrild, ,, ...	3	10	0			
Cooke and Sons, instruments	13	13	0			
Insurance	10	0	6			
				252	3	2
Miscellaneous items :—						
House expenses	26	8	3			
Postages	46	8	11			
Books and parcels	7	11	10			
Expenses of evening meetings	13	13	0			
Waiters attending meetings	3	17	0			
Coals and wood	12	0	0			
Gas	6	10	0			
Repairs	1	9	8			
Sundries	9	6	0			
				127	4	8
				619	10	8
Turnor Fund	1	13	6			
Mrs. Jackson's annuity, 1 year	8	15	6			
				10	9	0
Investment :—						
Purchase of £200 Consols...				188	5	0
Banker's Commission on Country Cheque				0	0	6
				818	5	2
Balance at Banker's				390	14	3
				1208	19	5
Add error of 4*d.* in the Petty Cash Account, carried to Petty Cash Account for 1869				0	0	4
				£1208	19	9

F. C. Penrose,
H. Perigal,
J. H. Dallmeyer,
} *Auditors.*

Assets and Present Property of the Society, January 1, 1869:—

	£	s.	d.	£	s.	d.
Balance at Banker's	...		...	390	14	3
2 Contributions of 7 years' standing ...	29	8	0			
9 ,, 5 ,, ...	94	10	0			
16 ,, 4 ,, ...	134	8	0			
10 ,, 3 ,, ...	63	0	0			
23 ,, 2 ,, ...	96	12	0			
36 ,, 1 ,, ...	75	12	0			
Balance of an Account...	5	10	0			
2 admission-fees, and first contributions ...	6	6	0			
				505	6	0
Due for Publications				2	14	6
£5000 New 3 Per Cents (including Mrs. Jackson's Gift, £300).						
£3000 Consols, including the Lee Fund (£100) and Turnor Fund (£500).						
Unsold Publications of the Society.						
Various astronomical instruments, books, prints, &c.						
Balance of Turnor Fund (included in Treasurer's Account)				125	18	0

Stock of volumes of the *Memoirs*:—

Vol.	Total.	Vol.	Total.	Vol.	Total.
I. Part 1	13	XI.	188	XXIV.	189
I. Part 2	53	XII.	194	XXV.	199
II. Part 1	71	XIII.	205	XXVI.	206
II. Part 2	35	XIV.	394	XXVII.	460
III. Part 1	88	XV.	177	XXVIII.	421
III. Part 2	107	XVI.	203	XXIX.	452
IV. Part 1	107	XVII.	185	XXX.	201
IV. Part 2	118	XVIII.	181	XXXI.	177
V.	128	XIX.	191	XXXII.	208
VI.	154	XX.	186	XXXIII.	215
VII.	178	XXI. Part 1	216	XXXIV.	213
VIII.	164	XXI. Part 2	100	XXXV.	185
IX.	167	XXI. (together).	94	XXXVI. (with M. N.)	267
X.	179	XXII.	185	XXXVI. (without)	68
		XXIII.	182		

The instruments belonging to the Society are as follows:—

The *Harrison* clock,
The *Owen* portable circle,
The *Beaufoy* circle,
The *Beaufoy* transit,
The *Herschelian* 7-foot telescope,
The *Greig* universal instrument,
The *Smeaton* equatorial,
The *Cavendish* apparatus,
The 7-foot Gregorian telescope (late Mr. Shearman's),
The Variation transit (late Mr. Shearman's),
The Universal quadrant by Abraham Sharp,
The *Fuller* theodolite,
The Standard scale,
The *Beaufoy* clock, No. 1,
The *Beaufoy* clock, No. 2,
The *Wollaston* telescope,
The *Lee* circle,
The *Sharpe* reflecting circle,
The *Brisbane* circle,
The *Short* universal instrument.

The *Sheepshanks*' collection of instruments, viz.,—

1. 30-inch transit, by Simms, with level and two iron stands.

2. 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.

3. $4\frac{6}{10}$ achromatic telescope, about 5 feet 6 inches focal length; finder, rack motion; double-image micrometer; object-glass micrometer; two other micrometers; one terrestrial and ten astronomical eyepieces, applied by means of two adapters, with equatorial stand and clock movement.

4. $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

5. $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

6. $2\frac{3}{4}$ achromatic telescope, about 30 inches focus; one terrestrial and four astronomical eyepieces.

7. 2-foot navy telescope.

8. 45-inch transit instrument, with iron stand, and also Y's for fixing to stone piers; two axis levels.

9. Repeating theodolite, by Ertel, with folding tripod stand.

10. 8-inch pillar-sextant, divided on platinum, with counter poise stand and horizon roof.

11. Portable zenith instrument, with detached micrometer and eyepiece.

12. 18-inch Borda's repeating circle, by Troughton.

13. 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms.

14. A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, with extra pair of parallel plates; tripod staff; in which the telescope tube is packed; repeating table; level collimator, with micrometer eyepiece; and Troughton's levelling staff.

15. Level collimator, plain diaphragm.

16. 10-inch reflecting circle, by Troughton, with counterpoise stand; artificial horizon, with metallic roof; two tripod stands, one with table for artificial horizon.

17. Hassler's reflecting circle, by Troughton, with counterpoise stand.

18. 6-inch reflecting circle, by Troughton, with two counterpoise stands, one with artificial horizon.

19. 5-inch reflecting circle, by Lenoir

20. Reflecting circle, by Jecker, of Paris.

21. Box sextant and 3-inch plane artificial horizon.

22. Prismatic compass.

23. Mountain barometer.

24. Prismatic compass.

25. 5-inch compass.

26. Dipping needle.

27. Intensity needle.

28. Ditto ditto.

29. Box of magnetic apparatus.

30. Hassler's reflecting circle, with artificial horizon roof.

31. Box sextant and $2\frac{1}{4}$-inch glass plane artificial horizon.

32. Plane speculum artificial horizon and stand.

33. $2\frac{1}{2}$-inch circular level horizon, by Dollond.

34. Artificial horizon roof and trough.

35. Set of drawing instruments, consisting of 6-inch circular protractor; common ditto; 2-foot plotting scale; two beam compasses and small T square.

36. A pentagraph.

37. A noddy.

38. A small Galilean telescope, with the object lens of rock-crystal.

39. Six levels, various.

40. 18-inch celestial globe.

41. Varley stand for telescope.

42. Thermometer.

43. Telescope, with the object-glass of rock crystal.

These are now in the apartments of the Society, with the exception of the following, which are lent, during the pleasure of the Council, to the several parties under mentioned, viz.:—

The *Fuller* theodolite, to the Director of the Sydney Observatory.

The *Beaufoy* transit, to the Observatory, Kingston, Canada.

The *Sheepshanks* instrument, No. 1, to Mr. Lassell.
Ditto ditto No. 3, to Major Tennant.
Ditto ditto No. 4, to Rev. C. Lowndes.
Ditto ditto No. 5, to Mr. Birt.
Ditto ditto No. 6, to Rev. J. Cape.
Ditto ditto No. 8, to Rev. C. Pritchard.
Ditto ditto No. 9, to the Director of the Sydney Observatory.
Ditto ditto No. 41, to Rev. C. Pritchard.
Ditto ditto No. 43, to Mr. Huggins.
The 6-inch circular protractor, to Mr. Birt.

The Gold Medal.

The Council have awarded the Gold Medal to Mr. E. J. Stone for his Rediscussion of the Observations of the Transit of *Venus* in 1769, and his other contributions to Astronomy. The President will, in the usual way, explain the grounds of this award.

Memoirs.

The next volume of *Memoirs* will contain Major Tennant's paper on the Solar Eclipse of August 18, 1868. The paper will be accompanied by engravings of the photographs, enlarged under the superintendence of Mr. Warren De La Rue.

Index to the Publications of the Society.

An index to all the papers contained in the publications of the Society, from its commencement down to the end of 1868, is nearly finished, and will shortly be forwarded to press. The index will contain all the papers contributed by each author under his name, and also a list of papers contributed under the head of each subject.

Obituary.

The Society has to regret the loss by death of the following Fellows and Associates:—

Fellows.—Philip James Chabot.
Sir David Brewster.
Rev. W. R. Dawes.
Thomas Cooke.
H. E. Westcar.

Major-General Shortrede.
Robert Porrett.
W. S. Downes.
John Jenkins.
W. H. Barton.
Robert Worthington.

Honorary Fellow.—The King of Siam.

Associate.—Leon Foucault.

The late Rev. William Rutter Dawes, Fellow of this Society, was born on the 19th of March, 1799, at Christ's Hospital, where his father was Mathematical Master. He lost his mother while very young, and, his father having been appointed Governor of Sierra Leone, he was placed under the care of his grandfather at Portsmouth. In 1807 he was transferred to the family of the Rev. Thomas Scott, the revered Commentator on the Bible, where he remained till 1811, in which year, on his father's return to England, he was placed at the Charter House. In 1813, however, on his father's again leaving England for the West Indies, he was removed thence and once more placed under the care of the Rev. Mr. Scott, at Aston Sandford, where he remained until the death of that excellent man, who breathed his last in his pupil's arms.

Designed by his father for a clergyman in the Church of England, he studied under Mr. Scott with that object in view. A mind like his, however, could not receive dogmas, however consecrated by general approval, without giving them a searching examination. In his case the result was, that he became dissatisfied as to some at least of the tenets of the Established Church, specially relating to ecclesiastical government. Instead, however, of rushing headlong in the opposite direction, young Mr. Dawes turned his thoughts to the study of Medicine, for which he was eminently qualified by nature. Having gone through the usual course at St. Bartholomew's Hospital, under Abernethy and the late Sir Wm. Lawrence, he returned to the neighbourhood which in Mr. Scott's society he had learned to love, and settled as a medical practitioner at Haddenham, Berks. Here he married his first wife, the widow of his late tutor and friend, who, though much older than himself, contributed greatly to his happiness by her vivacity and Christian gentleness.

Domestic arrangements arising out of the death of an only and very dear sister caused him, however, to give up his practice at Haddenham, and brought him to Liverpool in the year 1826. Here his former desire to take holy orders seemed to revive; but he was unable to escape from the scruples which had formerly deterred him from so doing in the Church of England. While in this unsettled state of mind, Mr. Dawes was brought into contact with the late Dr. Raffles, Minister of the leading Independent Congregation in Liverpool. A man possessing such gentlemanly

feelings, and acting on such enlarged and Christian principles, at once exercised a powerful influence over Mr. Dawes, and he was at length induced to take charge of a small congregation of the Independent denomination at Ormskirk. The name of this place is the first which is associated with him in that scientific career which he afterwards adorned. Partial to Astronomy from a youth (for he has left sketches of his observations while with Mr. Scott — a taste inherited from his father) — Mr. Dawes continued his observations while in Liverpool with a small telescope (of less than 2 inches aperture) through an open window.*

At Ormskirk, however, he erected his first Observatory; on a small scale, the principal instrument being a 5-foot refractor by Dollond, aperture 3·8 inches; and there became known as an earnest and precise observer. On the 14th May, 1830, he was elected a Fellow of the Royal Astronomical Society, and, his health having some time previously failed, he was compelled to resign his ministerial charge, and in the early autumn of 1839† he took charge of Mr. Bishop's Observatory at South Villa, Regent's Park; himself residing in St. John's Wood. While here, it was that he married a second time (his former wife having died at Ormskirk some years previously). This happy and judicious union with the widow of John Welsby, Esq., Solicitor, of Ormskirk, which occurred in 1842, contributed materially to the comfort and usefulness of his future life. Soon after, on the termination of his connexion with Mr. Bishop in the spring of 1844, Mr. Dawes removed to Cranbrook, in Kent, to a residence called Camden Lodge, where he erected the Observatory described in the sixteenth volume of the *Transactions* of this Society, which, in 1846, he enriched with a fine equatoreal telescope of 8½ feet focus and 6 inches aperture, by Merz, of Munich, admirably adapted by a most delicate clock-work movement for his observation and measurement of double-stars, and the satellites of *Saturn* and *Uranus*. With this he continued indefatigably to observe, suffering, however, deplorably from continual and most distressing headaches and other symptoms of increasing ill-health, which, at length, obliged him to resort to a residence at Torquay, and had

* This was probably the telescope referred to in the following extract from one of his letters, dated 17 Dec. 1867, addressed to Sir J. Herschel: —

"Having obtained the loan of a volume of Rees's *Encyclopædia*, I had copied out the list it contained of Sir Wm. Herschel's Catalogues of Double-Stars, arranged in classes and constellations; and with a capital little refractor of only 1·6 inches aperture, and a copy of the French edition of Flamsteed's Atlas, which was presented by Dr. Maskelyne to my father before he went out in 1787 as Government Astronomer to the first expedition to Botany Bay under Governor Philip. I worked away on almost every fine night, when uncertain health would permit, and found and distinctly made out a large number of the objects in the second and third classes, among which were *Castor*, *Rigel*, ε^1 and ε^2 *Lyræ*, σ *Orionis*, ζ *Aquarii*, and many others, of which I made correct diagrams in a book now lying before me, as well as of γ *Virginis* (then in the same quadrant that it is now), *Polaris*, &c. &c. The difficulty often was to get to bed in summer before the Sun extinguished the sight of the game."

† Some time between Aug. 10 and Oct. 1.

nearly decided him to dispose of his instruments and give up observing. A favourable change, however, took place, and in 1850 he removed his observatory to Wateringbury, near Maidstone, and finally, in 1857, to Hopefield, Haddenham, near Thame, where he continued to reside till his decease. Here it was that the accurate observations and ripened experience of many years bore their fruit in the universal esteem with which they were regarded, as well as in the volume completed and printed just before his death by the Astronomical Society, under the title of "Catalogue of Micrometrical Measures of Double Stars," forming part of the thirty-fifth volume of their *Transactions*. This work, taken in conjunction with the earlier series of measures of 121 double-stars, contained in vol. viii. of the *Mem. R. Ast. Soc.*, and of his Ormskirk Measures, communicated to the Astronomical Society in 1849–50, and forming part of the nineteenth volume of their *Memoirs*, and with those made with Mr. Bishop's 7-inch refractor from 1839 to 1844, published by that gentleman in a separate volume of observations at South Villa, form a monument of unwearied industry and minute and painstaking precision, to which it would be difficult to find a parallel in the record of private and unassisted observation. The instrumental means at his disposal in the interval from 1854 to 1865 were augmented by the purchase in 1854 of an admirable $7\frac{1}{2}$-inch refractor by Alvan Clarke, which was replaced in May 1859 by a still larger instrument by the same maker of $8\frac{1}{4}$ inches clear aperture and 110 inches focus, equatoreally mounted, at Haddenham, as described in the *Ast. Soc. Notices*, vol. xx. p. 60. Many of his measures, too, commencing with April 13, 1865, were made with an 8-inch refractor by Messrs. Cooke and Son, so that nothing which instrumental means could supply is wanting to render these later observations landmarks of ultimate and invaluable reference in this department of Astronomy.

In the year 1855 Mr. Dawes was presented with the Gold Medal of the Royal Astronomical Society. In his address to the Society on that occasion, the Astronomer Royal (the President for the year), while laying all due stress on the excellence of Mr. Dawes's measurements of double-stars from 1831 to 1844, very properly calls attention to his *independent discovery* in (Nov. 25 and 29) 1850 of the interior dusky ring of *Saturn*, noticed by Prof. Bond on the other side of the Atlantic, on Nov. 15th of the same year, of which observation the first account reached England on Dec. 3d. The astonishing phenomena of the total Solar Eclipse of 1851, too, as he states in the same address, were observed by Mr. Dawes, who made the voyage to Sweden for that purpose.

In 1865 Mr. Dawes was elected a Fellow of the Royal Society.

Endowed with great perseverance and schooled to great accuracy of observation and description, Mr. Dawes's contributions to astronomical science will ever be regarded as of high value.

He possessed also great ingenuity, and was constantly experimenting. His solar eye-piece, which, by stopping out the blinding light of the photosphere, allows us to obtain a distinct and prolonged view of the interior or nuclear portion of the spots, has afforded us as its practical result, the knowledge of the existence of an interior envelope of the Sun's body which had never before been suspected.

Devoted as he was to Astronomy, the subject of this brief notice was ever ready to impart gratuitous advice to the sick, and will be remembered as their benefactor for years to come by the families of the poor inhabitants of Haddenham; and while his name is known and revered among the learned of different nations and remembered with affection by his relations and friends, it will ever be cherished with grateful feelings by the many recipients of his seasonable medical advice and treatment.

After the loss of his second wife, which occurred in December 1860, his health, always feeble, as a natural consequence of the deep depression of his spirits, gradually gave way. In addition to his habitual and distressing headaches, and attacks of nervous and spasmodic asthma, a heart affection manifested itself, rendering perfect stillness for hours together, and avoidance of the slightest excitement, necessary.

In the intervals of comparative ease accorded him from these attacks, however, he was able to continue his observations, the results of which up to the middle of 1865 (so far as the measurements of Double Stars are concerned)are given in an Appendix to the great Catalogue already spoken of. Much of his attention, too, was given to the discussion as to the nature of that peculiar mottling of the solar photosphere which has been compared to "willow-leaves" and to "rice-grains," but in which he could never be brought to allow that kind of generic form and magnitude which would go to stamp them as "entities" of some special kind modelled according to some definite type: likening them (while not denying their occasional and even frequent visibility as bodies having *size* and distinguishable *shape*) rather to bits of straw or irregular flocculi; nor can this persistent testimony, coming from an observer of such singular acuteness of vision and of such unwearied patience in scrutiny, be lightly cast aside.

Two years before his death Mr. Dawes had a serious attack of illness, from which he so far rallied that his friends hoped his valuable life might yet have been spared many years. Some weeks before his last attack he had been ailing, and seemed prepared for something serious. Up to the last he retained the entire possession of his faculties and his interest in his astronomical pursuits. Only twenty-four hours previous to his decease he had his "Measurements" on his knee in bed, explaining something there to his medical attendant.

Combined with an ardent, inquiring, and mathematically reasoning mind, Mr. Dawes possessed an implicit and childlike faith in the great doctrines of Revelation, and, though ready to dispute

many of the accepted theories of theology, never for a moment let go the cardinal doctrine of salvation by faith only in our Lord Jesus Christ. After some hours of unconsciousness, he peacefully breathed his last on Feb. 15, 1868, and lies interred beside his dear wife in the churchyard of Haddenham.*

The late Major-General Robert Shortrede was born at Jedburgh, in Roxburghshire, on the 19th July, 1800, and was the son of Mr. Robert Shortrede, Procurator-Fiscal of that county. He was educated first at the Jedburgh Grammar School, and afterwards at the Edinburgh High School, whence he went to Edinburgh University, where he attended the Mathematical and Natural Philosophy classes for four years, and attained considerable distinction. During that time he was also in the office of Mr. Robert Stevenson, the engineer of the Northern Lighthouses, as he was originally intended for a civil engineer, having early evinced unusual aptitude for Mathematics; but his friends, thinking that India presented ample scope for his talents in that direction, he obtained an appointment to that country from the late Mr. Canning, through the influence of Sir Walter Scott, an old and intimate friend of his family; but unfortunately he was then too old to go to Addiscombe, and so into the Engineers in the usual course, and was therefore obliged to enter the Infantry of the line, which he afterwards found to be a serious hindrance to his scientific advancement. Shortly after his arrival in India in 1822, he was appointed to the Deccan Survey, and was soon afterwards employed to conduct a triangulation over the Bombay Presidency, in the course of which he measured a base-line on the Karleh Plain, which when connected with that from Seronj by the Bombay Longitudinal Series, has proved to be not inferior in correctness to bases measured in the Great Arc. In 1834 at the request of Lord Clare's government, he was appointed to examine and report upon an extensive Revenue Survey and Assessment of the Deccan, in the course of which it was believed that great frauds had been committed. For the manner in which this duty was performed he received the thanks of Government, and shortly afterwards, without solicitation on his part, was put in civil charge of a district which had long been in disorder, with almost discretionary power, to revise the rates, and put it into order generally. He lowered the assessment and increased the revenue, and in the course of two years brought 40,000 acres of land into cultivation on moderately increasing leases. While so employed he had a dangerous illness, and before the end of his sick-leave, on the sudden death of the Mint Engineer, he was employed for a few months as assistant in the Mint until some permanent arrangement could be made. Shortly afterwards Captain Jacob, then Astronomer at Madras, went on sick-leave to the Cape, and Captain Shortrede was put in charge of the work till

* The leading biographical features of this notice were communicated by, and are given in great measure in the words of, a near relative of the deceased.

his return. He was afterwards permanently appointed to the Great Trigonometrical Survey, in which he remained till 1845, when he came home home on sick-leave, and while in England drew out a paper on the attraction of the Himalayas as affecting the northern end of the Great Arc, which was shown to and approved of by Lieutenant Raper, Admiral Smyth, Sir J. Lubbock, and Sir J. Herschel, and afterwards submitted to the Royal Astronomical Society, and printed in their *Transactions* for 1845. He also published at this time some Mathematical and Logarithmic Tables, probably the most extensive and correct ever published by a private individual without a subscription list, and which have received the approval of several distinguished mathematicians and astronomers, both British and foreign, amongst others the Astronomer Royal. In 1849, he returned to India, and was appointed to the Revenue Survey in the Punjaub, where he remained till 1856, when he was ordered with his regiment (the Second Bombay Europeans) to Persia, and served through that campaign: he returned to England in 1859. He soon afterwards retired, since which time he published some Traverse Tables, and was engaged at the time of his death in correcting the proofs of some Navigation Tables, compiled with a view to facilitate keeping a reckoning at sea. Throughout his career he was an earnest Christian and philanthropist. He died at Blackheath after a few hours' illness from disease of the heart, on the 26th November, 1868, aged 68.

Mr. John Jenkins was born in London in 1802; while young he accompanied his parents to Swansea, where he subsequently carried on the business of a watch and chronometer-maker,—a vocation which seems to have had considerable influence in determining his pursuits in after years. His contributions to local scientific observation commenced at an early period of his life. His meteorological observations were conducted during a long series of years, and the voluminous tables supplied by him on occasions of more than one official inquiry, attest his unwearied industry, while they obtained for him the admiration and esteem of eminent scientific men engaged in those inquiries. In 1842, Mr. Jenkins accomplished his long-cherished wish of erecting an observatory on his business premises in Swansea. In effecting this object he consulted not only his own tastes for astronomical observation, but the convenience of the numerous foreign trading vessels which about this time began to resort to the port; the observatory was open to all masters and other officers of ships trading to Swansea. It may be remarked that the transit instrument in this observatory was fitted up under the personal superintendence of the late Mr. Sheepshanks, for whom Mr. Jenkins entertained the highest regard, and through whose instrumentality he became a fellow of the Royal Astronomical Society. Here after the business engagements of the day, Mr. Jenkins was for many years in the habit of devoting the hours of night to astronomical observation. In all local efforts for the promotion of the

interests of science and the diffusion of useful knowledge Mr. Jenkins took an active and often a prominent part. His labours on behalf of the Royal Institution of South Wales were for many years unremitting, and were duly acknowledged by that body on his retirement from official connexion with it some two years since. Referring to organisations of a more popular character for the diffusion of scientific knowledge, so long ago as 1826 we find Mr. Jenkins a prominent promoter of the first attempt to establish a Mechanics' Institution in the town of Swansea, and in all subsequent efforts for the same object he was equally prompt in giving personal services and pecuniary aid to the cause of popular enlightenment, while his sympathies with the social and moral amelioration of the industrial classes are attested by the fact recorded in a local notice of his death that "his patient labours over many years in the promotion of Benefit Building Societies in Swansea and in its neighbourhood give him signal claims to public remembrance." Mr. Jenkins retired from the business which he had so successfully conducted some fifteen years since. For the past three years he had been in declining health from a disease, the sufferings of which he bore with fortitude and equanimity, but under which he finally sank, leaving behind him the cherished recollection of one who, according to his opportunities, had well discharged the "stewardship of life." He died at his residence, Rotherslade, Swansea, on December 16, 1868.

Mr. William Samuel Downes was the eldest son of Mr. James John Downes, whose death was recorded in last year's Report. He evinced in early life great literary and scientific ability, but receiving at the early age of twenty-seven the important and responsible appointment of actuary and secretary to the Law Life Assurance Society, he thenceforth devoted his whole mind to the conduct of the affairs of that important institution. He was one of the founders of the Actuaries' Club, and acted as its treasurer for some time. He died on the 5th of December, 1868, in the forty-ninth year of his age.

Robert Porrett was born in 1782. His father held the office of Ordnance Store-keeper in the Tower, to which office the subject of the present memoir succeeded at his decease. He became a member of the Spitalfields Mathematical Society in 1811. He was an experienced chemist. His first communication in that science was printed in the *Transactions of the Society of Arts*, vol. xxvii. 1809, it is entitled "On Prussic and Prussous Acids." In 1813, in conjunction with Messrs. Wilson and Rupert Kirk, he published an important series of experiments on the explosive compound of chlorine and nitrogen, in vol. xxxiv. of Nicholson's *Journal*. The *Phil. Trans.* for 1814 contain a paper of his "On Triple Prussiates and on Acids formed by the Element of Prussic Acid with Sulphur," and another entitled "On the Constitution of the Prussic, Ferro-chyasic, and Sulpho-chyasic Acids." He gave the name of ferro-chyasic acid to that acid chemists

now call hydrogen ferro-cyanide, from its being compounded of iron, carbon, hydrogen, and nitrogen. His investigations on endosmose or the elective transmission of liquids through a membranous diaphragm was published in the *Annals of Philosophy*, vol. viii. 1816. This curious property of membranes has since been thoroughly investigated by Prof. Graham, whose researches have ultimately led to a new method of analysis called "dialysis." He contributed many valuable essays to the other scientific journals, the latest in conjunction with the late Mr. Teschmacher was read before the Chemical Society in 1846, it is entitled, "On the Composition of Gun-cotton." Throughout his career as a chemist he was distinguished for the great originality of his views. He was elected a Fellow of the Royal Society in 1848, and was also a Fellow of the Society of Antiquaries and of the Chemical Society. He became a Fellow of this Society on its junction with the Mathematical Society in 1845. In addition to his chemical pursuits he was much devoted to antiquarian researches, particularly as connected with ancient weapons and armour, and was always ready to give any information in his power on such subjects. He was for many years Treasurer of the Chemical Society, and was on more than one occasion pressed to accept the Presidentship, which he declined on the ground of his advanced age, which, however, did not prevent his being a frequent attendant at the meetings of the various scientific Societies with which he was connected. He died on the 25th of November, 1868.

Philip James Chabot was born in Spitalfields in 1801. His father, who was descended from one of the refugees who were obliged to leave their native country in consequence of the Revocation of the Edict of Nantes, was an eminent dyer in that parish. After the usual classical education, Mr. Chabot entered at St. John's College, Cambridge, and took his degree of M.A. in 1827. In 1830 he was called to the Bar, but, on the decease of his father in 1832, he was induced by the earnest entreaties of his friends, although much against his own inclination, to quit the legal profession and engage in his late father's business as a dyer. He subsequently made several improvements in some of the branches of dyeing; but finding the business did not answer his expectations, he retired from it, and became the originator of the Silk Conditioning Society, of which he was Secretary and Manager to the time of his death. He was elected a Member of the Spitalfields Mathematical Society in 1834, and at the junction of that Society with this in 1845, he became a Fellow of this Society. He was a Member of the Cavendish and Philological Societies, and also of the Chemical Society, from which he had retired a few years before his death. He was a well-read and intelligent man, and much interested in science and general literature, and was greatly respected for his probity and urbanity of manners. He died suddenly January 11, 1868.

William Parsons, Earl of Rosse, the eldest son of Lawrence,

the second Earl, was born at York on the 17th of June, 1800. His mother was Alice, daughter of John Lloyd, Esq., of Gloster, King's County. His preparatory education he received at home, from a private tutor, and in 1818 he entered the University of Dublin; remaining there, however, only till the following year, when he passed to Magdalen College, Oxford. Here he took high honours, receiving his B.A. degree as a First Class in Mathematics, in 1822. While bearing the title of Lord Oxmantown he was elected to represent King's County, and sat in Parliament from 1821 till 1834, when he retired from political life — for a while only, however—to devote himself more closely to the duties of his social position, and to follow with greater freedom the philosophical pursuits into which the bent of his mind had led him. In the meanwhile, in 1831, he had been appointed Lord Lieutenant of his County, and in 1834 he was made Colonel of its Militia. Two years after this he was married to Mary, eldest daughter of the late John Wilmer Field, Esq. of Heaton Hall, Yorkshire: in 1840 the present Earl, the eldest of four sons, was born.

The second Earl died in the year 1841, and the subject of this memoir succeeded to the title; but his Irish coronet giving him no seat in the House of Lords, he was still enabled to pursue without serious interruption the objects of his scientific taste. In 1845, however, he was elected an Irish Representative Peer, and thus he held a seat for life in the House of Lords. Although he occupied it with good regularity, he took little active part in debate: his voice was seldom, if ever, heard during the stormy period which embraced the discussions upon Irish Emancipation and Reform. But if not a talking, he was a working member, an invaluable referee in matters of business, and an assiduous servant upon committees. Throughout his Parliamentary career he gave his support to the Conservative party. Dwelling among an excited people in troublous times, he was firm in enforcing the authority of the law, even to the risk of his own personal safety; but withal he was kind and beneficent, devoting nearly all the rental of his Irish property to the relief of his suffering countrymen, thereby winning for himself a place in their hearts, and in time diverting the hostile feelings with which he had been regarded. His genius was eminently versatile. One among his friends, who had the best opportunities for discerning the extent and varied nature of his abilities, tells us that few minds of our day have grasped so wide a range of knowledge. Of his engineering skill and his mechanical resource he has left us monuments that speak for themselves; but of his mastery of political economy, of his capacity as a chemist, of his acquaintance with military and nautical sciences, he has left us no such memorials, though it was quite in his power to have created them.

Astronomy was the science of his adoption; the manufacture of stupendous telescopes the branch of it to which he devoted undivided attention. It was his aim to extend this to its farthest limit of practicability; to make a telescope of the largest dimensions possible with the resources of his time. The reflecting

principle was that to which he was compelled to resort. There was no hope of any such immediate advance in the manufacture of optical glass as would supply disks of the size and quality requisite to surpass to any degree the refractors then in use. We are speaking of the date of his first turning attention to the subject, which was about 1826. He made some few experiments upon fluid lenses, but these gave no promise. To perfect the reflector was the only course open to him. But it was one beset with difficulties that could be foreseen, and obstacles that arose only as the work grew under his hand. To start with, the Earl of Rosse had to originate everything; the experiences of his predecessors in the same domain of art were of no avail to him. Short, who had excelled all who went before him in casting and polishing specula, was so jealous of posterity reaping the fruits of his knowledge, that before his death he ordered all his tools to be destroyed. The Earl of Stanhope made great endeavours to attain magnitude in reflecting telescopes, but his attempts were failures. He bequeathed his papers to the Royal Institution, and Sir James South searched them through for memoranda bearing upon the subject, thinking that the failures of such a man might in their way be instructive; but he did not light on a single hint that was worth remembering. Sir William Herschel was the master who, from the majestic scale of his instruments, might have been expected to have given the Earl of Rosse an example to work from; but his methods were a sealed book — what was the composition of his metals and how he worked them to figure and polish have never been made known.

The inaugural difficulty was in the selection of an alloy possessing the qualities of whiteness, brilliancy, and resistance to tarnish requisite for a mirror. After many trials a mixture was decided upon as answering these conditions,—an alloy of four atoms of copper to one of tin. But such a compound, though harder than steel, is more brittle than glass, very unmanageable in the founder's hands, not yielding a sound casting by ordinary processes, and when cast liable to crack in cooling, or afterwards by any sudden change of temperature. To form a large speculum in one mass of such material seemed impossible, and Lord Rosse was led to the expedient of building one up of small segments, separately cast and polished, and united upon a foundation-plate formed of a brass specially prepared that its temperature expansion should be identical with that of the speculum metal. Repeated trials upon a small scale were made, and at length a mirror of 3-feet diameter was completed, which performed well upon small stars, but that exhibited its divisions upon the disk of a large star. In the course, however, of the foundry experiments upon plates from which to cut the parts of composite specula, Lord Rosse was led to a method of casting sound slabs of metal of large size at one operation. The points to be secured were, cooling without cracking, and freedom from pores or air-bubbles. The ordinary sand-mould allowed the edges of the

plates to solidify first, and the central portions were confined and strained when their moment of cooling came, and this was the cause of cracking. It occurred to Lord Rosse that if the metal could be cooled from its lower surface upwards, in laminæ or strata, as it were, the upper surface being the last to solidify, this evil would be remedied. He tried an iron mould and threw a jet of water upon its under surface when the molten metal was within. This answered the immediate end, but the iron cracked and spoilt the casting. The next idea was to make the mould with a stout iron bottom and sand circumference, and trust to the abstraction of heat by the iron alone to cool the metal from below. This succeeded; but another evil betrayed itself: the air entangled between the speculum metal and the iron, formed large cavities that ruined the disk; in the porous sand-moulds it found a ready exit. The removal of this defect was the culminating triumph in this department of the noble founder's labours. Equal to every emergency he proceeded to make a ventilating bottom for his mould: he took thin bands of iron and closely packed them edgewise into a frame the size of the intended speculum, so that instead of a solid plate he had a surface somewhat like a book-edge; close enough to prevent the viscous metal from leaking out, but porous enough to allow the air to escape freely. The face of such a disk, turned in a lathe to the desired convexity and made smooth, formed the base of a mould, which, with a sand ring for its sides, permitted the casting of sixteen slabs for 3-feet specula, of which not one was defective. This improvement removed the last barrier to the casting of mirrors of any required diameter.

After meeting and surmounting more difficulties connected with the manufacture of crucibles, and after the exercise of anxious patience during the fortnight occupied by the cooling of the metal in an annealing oven, Lord Rosse obtained a 3-foot disk without fault or blemish, ready for the operations of grinding and polishing. It had been thought that the hand of a workman was the only fit guide for the polishing tool of a reflector, that the process was one which must be *felt* to be successfully followed. Such a notion was a manifest impediment to attempt, even in the manuafacture of large telescopes. Lord Rosse was compelled at an early stage of his experiments to resort to machine power. The manual operation of figuring a speculum is pretty well known: the tool is mounted upon a pedestal, and the workman, grasping the metal disk, gives it a rectilinear or curvilinear motion in a direction perpendicular to the plane of his body, at the same time walking round the pedestal. To reproduce these combined motions, with the means of methodically altering them and maintaining them in their altered condition, was the object of the polishing apparatus invented by Lord Rosse in 1828, and which was employed, with small modifications, in the many hundred grindings and polishings which he caused to be performed. The drawing and description of the machine are to be found in

the *Philosophical Transactions* for 1840, and elsewhere; it is not necessary that we should describe it further than by saying that while the speculum rotates horizontally in a bath of water, for preservation of a uniform temperature, the polishing tool, weighted as may be necessary, lies upon it, and moves either in a straight line or in an ellipse the relation of whose axis is varied by adjustible eccentrics carrying the rod to which the tool is attached. With this mechanism every motion could be defined, and its effect upon the speculum's figure ascertained; a particular result once obtained could be repeated at will; and a precision in the figuring of reflectors was secured which, till this system was introduced, had been out of reach.

All difficulties of grinding overcome, and the figure tested by the image of a watch dial carried on a mast fifty feet above the polishing machine—so that the trials could be made without moving the speculum—new obstacles arose in the process of polishing. The grinding tool was covered with pitch to form the polisher, but the unequal expansion of the bituminous layer, by pressure and rubbing, destroyed its form, so that it would no longer fit the speculum, but chafed it untruly. This difficulty, never felt in working small mirrors, because the pitch layer can expand equally where its area is small, was a puzzling one to Lord Rosse working upon his large scale. But he overcame it at last, by scoring the resinous surface of the tool with grooves, and subsequently, as even this plan sometimes failed, by furrowing the iron tool itself. So long as the pitch was soft enough to escape into the grooves, all went well, but this softness was an impediment to the production of a true figure, which required that the medium for holding the particles of polishing powder should be as hard as possible. It takes a short time to relate what took a long time to invent. Two opposite properties, hardness and softness, were united in the resinous coating: first a layer of soft resin—which Lord Rosse eventually preferred to pitch—was applied, and then a layer of hard; the first acted as a cushion to the second, and thus the requisite conditions were realised. This was the final remedy of the final difficulty in the way of constructing great reflectors.

Such is an imperfect outline of the major obstacles that the Earl of Rosse encountered and overthrew during the twelve years ending with 1840, the date at which the 3-foot speculum was finally perfected. Of the minor embarrassments and perplexities we know nothing; but they must have been numberless. Throughout his original memoir are scattered modest sentences such as "after many difficulties" or "as the result of repeated trials," which must cover cares and anxieties beyond the appreciation of those who have not in some degree experienced similar troubles. The perfection of a great invention or a great instrument is rarely the work of a single labourer, but to the honour of Lord Rosse be it recorded that, unaided, he perfected the reflecting telescope. The 3-foot mirror, supported and mounted, surpassed, so far as

comparisons could be inferred, the definition and power of the larger telescope of Sir William Herschel, and this was the only predecessor that could be considered to compete with it.

Yet after all it was but the stepping-stone to higher ends. Lord Rosse now saw no impossibility in doubling the dimensions he had already attained, and he immediately determined upon attempting, or rather achieving — for with him the words were synonymous—a 6-foot speculum. Undeterred by predictions of failure, he set about the task. The leap from a mirror weighing a ton and a quarter to one whose weight would be four tons and a half involved new contrivances and precautions. But so thoroughly had Lord Rosse mastered every point of the process that every difficulty could be foreseen and provided for. This was done so completely that no trying back was necessary, no single operation or piece of work had to be repeated. The principles of forming the mirror were perfectly similar to those worked out for the 3-foot; only enlargement of means were necessary. The crucibles and melting furnaces had to be multiplied, and an annealing oven specially built to receive the stupendous casting; and the grinding and polishing machine had to be adapted to the larger size. The mounting of the instrument necessarily differed considerably from that of the 3-foot, which was similar to the older instruments of Herschel and Ramage. It was evident that the pyramidal frame of ladders which gave stability in their case would fail upon the scale of their giant successor. So it was resolved to sacrifice a large part of the sky view, and mount the instrument between two walls or piers, thus limiting its range to half an hour on each side of the meridian, at the equator, but giving it range in altitude from near the south horizon to below the pole. It may be that in this restriction we have an indication of the approach to impracticable magnitude, although Lord Rosse affirmed that a larger reflector than this could be made and would be of service, and held that where observations are systematically carried on the confinement in Right Ascension was no great disadvantage.

The great speculum was cast on the 13th of April, 1842, the eve, by the way, of his lordship's wedding anniversary, and was completely mounted for use by February, 1845, when Dr. Robinson and Sir James South visited it to make some inaugural observations. The latter observer gave his impressions in a lengthy letter to the *Times* of April 16 of that year. His comments are full of enthusiasm and admiration for the sights which he beheld, and which he avowed had never been gazed upon by man before. Dr. Robinson's experiences were given verbally to the Royal Irish Academy almost upon the same day. We need not dwell upon his remarks, interesting and instructive as they are, for in the descriptions of the instrument's work during the subsequent years of its use we have a wider view of its capabilities. We have seen how it has with certainty resolved certain of the nebulæ, and how, for a while, till spectrum analysis arose to arrest the conclusions it

tempted, it threatened to disprove the existence of such things as nebulæ at all by bringing all the objects so called within the domain of star-clusters; and we have seen how it has in this same class of bodies revealed a structure and arrangement more wonderful and inexplicable than anything which had hitherto been known to exist—we allude to the spiral conformation in all its varying conditions; we have seen, too, how it has necessitated some modifications in our previous ideas regarding planetary nebulæ, by breaking up the symmetric outlines that gave them their distinctive name. Lastly, we have seen, in the memoir recently published, that the views it has given of the nebula in *Orion* at intervals of fifteen years, as recorded by trustworthy draughtsmen, betray strong indications of change in the disposition of certain parts of the nebulous matter. On this point, as on many others, the instrument may yet yield results surpassing anything yet reaped from it; indeed its work, presided over by a new master inheriting the astronomical tastes of its founder, may be said to have but just begun. Already the spectroscope has been applied to it, and a few steps have been taken into that field of research for which, from its light-grasping power, it is so peculiarly fitted—the analysis of the light of the fainter stars and nebulæ. To pursue this a clock-movement is necessary; one is being, or by this time has been applied; so that ere long we may reap a harvest of knowledge upon a subject that was unknown when the instrument was designed, and thus will be added new honour to the fame of its designer.

The scientific life of the Earl of Rosse is the history of the leviathan telescopes. Their achievements are his renown. Posterity will esteem him rather as an engineering than as an observing astronomer. The honour that in the department of mechanical science we should accord to the great machine-tool makers who have rendered our age famous belongs in the department of astronomy to him. There is no disparagement implied in this comparison: far otherwise. It may justly be urged that the maker is above the user of an implement. Eyes are common to us all, all could make discoveries if they had the means. It was the means that the Earl of Rosse supplied. In his instruments we have the fruits of varied resources that are seldom combined in a single individual; great mechanical ability, optical and general scientific knowledge, and a large fortune; to these may be added indomitable perseverance and an imperturbable temper. Without these last the works he projected must have broken down. Be it remembered that he had no skilled workmen to help him, but drew all his personal assistance from the labourers about his estate, and he had to educate every man to the work. Everything was done in his own workshops and laboratory, even his steam-engine was of home construction, and at one time he was compelled to cast his own crucibles for the founding of his specula. But for the happy union of tastes, abilities, and means, such an instrument as the 6-foot reflector could not, in its time at least, have been

brought into existence; the undertaking would have been beyond the powers of professional instrument-makers, and beyond the purse of any individual or body likely to be interested in its prosecution. Since, however, its maker proved the possibility of producing perfect mirrors of immense size by mechanical means, others, profiting by his experience and advice, fully published and freely imparted, have excelled in the work, and now a 4-foot reflector, constructed by Mr. Grubb, under the superintendence of a committee, of whom Lord Rosse was one, has been sent to Australia to re-explore the depths of the Southern skies. Lord Rosse's freedom in making his methods accessible to the world will be remembered with gratitude by those who may follow him in the same field of labour; and by those of us who have no such object it must not be overlooked, for it shows us that his aim was not the vainglorious possession of something beyond the reach of his fellow-men—in which case he would have preserved silence—but the extension of Astronomical research in his own and succeeding generations.

His Lordship joined this Society in 1824, and the Royal Society in 1831; he was President of the latter from 1849 to 1854, and received its Royal Medal, for his telescopic triumphs, in 1851. He presided over the British Association Meeting at Cork in 1843; and he was a Visitor of the Maynooth College and a Member of the Visiting Board of the Greenwich Observatory. During the last six years of his life he filled the post of Chancellor of Trinity College, Dublin. He died at his seat and the scene of his life's labours, Birr Castle, Parsonstown, King's County, on the 31st of October, 1867, from the effects of a surgical operation—the removal of a tumour produced by a slight sprain of the knee. His remains were deposited in the Church of St. Brandon, Parsonstown, having been followed to their resting-place by some 4000 of the tenantry on his estates, by whom he had been deservedly beloved. [J. C.]

Thomas Cooke, by the combined force of his character and his genius, raised himself from a very humble sphere in an obscure village to a foremost place among that long line of eminent opticians who have contributed in no small degree to sustain the high reputation of England for practical science.

He was born on the 8th of March, 1807, at Allerthorpe, in the East Riding of Yorkshire; his father being a shoemaker in that village. So straitened were the circumstances of his home, that, although the boy in many ways showed tokens of no common abilities, nevertheless his father could afford him no better education than that provided by the National School, and even this instruction was limited to the space of two years. For this reason he was, at an early age, put to his father's trade, but for this trade young Cooke appears from the first to have felt an unconquerable aversion. The boy was for ever thinking of

Astronomy rather than of the mending of shoes. In those days, some of us can well remember how the voyages of Captain Cook exercised a wonderful fascination over young minds, and even now they might with great advantage displace much of the current literature of the times: over young Cooke's mind the fascination was irresistible. His bent was for the sea, and he would become, he said, a second Captain Cooke. But even here that common sense and practical side of the boy's character presented itself, which at later periods of his life became so salient a part of the character of the man. Thus, in selecting for himself the life of a sailor, he was so far from being a visionary, that he set himself at once to learn navigation, in order that he might make himself a good seaman. When, however, all was prepared for the final step, and young Cooke was on the point of starting on his new career, the entreaties and the tears of his mother prevailed on his feelings, naturally affectionate, and he set himself to consider in what way he could provide for his own maintenance nearer home. He renewed his studies with such small aids as he could procure, and in his seventeenth year he opened a village school. In this occupation he persevered until the age of twenty-two. This was the chief period when young Cooke was educating his own mind, and those who in after years had the pleasure of freely conversing with him on a variety of topics, must have been very sensible of the solid and successful nature of the result.

About the year 1829 he removed from Allerthorpe to York, where, for the next seven years he supported himself partly as an assistant-master in schools, and partly by private tuition. Such time as he could spare from this laborious and more remunerative occupation he devoted to mathematics and practical mechanics. In due course his thoughts were directed to the science of Optics, and, as was natural to one of his practical turn of mind, he attempted the construction of a reflecting telescope. Not satisfied with what he considered the uncertainty of the results of this form of instrument, and his pecuniary resources being unequal to the purchase of the requisite metals, he turned his attention to the manufacture of an achromatic object-glass. The material for one of the lenses he found in the bottom of an ordinary drinking glass; and although he had never seen the practical methods of grinding and polishing lenses, he at length succeeded, after many and wearisome trials, in producing a small achromatic telescope, the performance of which was sufficiently satisfactory to encourage him to further efforts. This telescope was subsequently purchased by Professor Phillips, of Oxford, who at that time was the centre of intellectual activity in York: no wonder that he was then, and continued to the last, the kind, warm friend of such a man as Cooke. For the counsel and encouragement afforded by that eminent *savant*, Mr. Cooke often expressed his gratitude in the hearing of the writer of this notice. Other friends also in York came forward, and held out the right hand of

fellowship to one in whom they discerned the evidences of no ordinary gifts.

With much hesitation and misgiving, Mr. Cooke now exchanged his avocation of a private teacher, the pecuniary returns of which, however inconsiderable, were in a measure certain, for the greater uncertainties of the business of an optician in York. Mr. William Gray, a Fellow of this Society, had the honour of giving him his first considerable order. It was for an equatoreally mounted telescope of $4\frac{1}{2}$ inches aperture. Thirty years ago there were scarcely any telescopes of even that moderate aperture in this country, executed by English artists. It was not on account of any want of skill on the part of our native opticians, but mainly owing to unwise fiscal arrangements in relation to the excise on glass, that it was then customary to send for the few considerable telescopes required, to the successors of Frauenhofer at Munich. Hence it was nothing short of an important event at that time, for an English artist to undertake the construction of a large telescope, and still more so for a man, as yet unknown to fame, and living in a provincial town. Since that day matters in this respect have greatly improved, and at the present moment there is probably no astronomical or optical instrument which cannot be procured from one or another of our great native artists, on pecuniary terms quite as favourable, and of a quality at least as excellent, as any that can be procured from abroad. In effecting this result for the achromatic telescope, Mr. Cooke was a great pioneer.

Mr. Cooke appears to have considered that the success attending Mr. Gray's telescope laid the foundation of his fame as an optician. In 1851, an order was given by Mr. Pattinson of Gateshead, for an equatoreal instrument completely mounted in every respect, and of the then considerable aperture of 7 inches. This instrument, by its excellence, greatly contributed to the growing reputation of the artist. It was this telescope which was so munificently placed by its owner at the disposal of Professor Piazzi Smyth for the purposes of his well-known expedition to Teneriffe.

Orders now flowed to Mr. Cooke for specimens of his art, which more than tasked his limited means to supply. In consequence of this agreeable pressure, he purchased some land in Bishophill, York, and there erected those workshops which are now known as the Buckingham Works. Thither he carried his business in 1855, with but five or six workmen and one apprentice: at the present time they furnish employment for upwards of one hundred persons.

Mr. Cooke's reputation was thus established, and in the course of a very few years he constructed no less a number than nine complete equatoreals, having apertures varying from 8 to 10 inches. Some twelve or thirteen others were also constructed, varying from 5 to 8 inches in aperture, the smallest of which deserved the name of a noble instrument. It is a fact worthy

of remark that all these large telescopes were commissions given to him by *private individuals*, living in a country of so small area as our own.

In the successful manufacture of the telescope with its elaborate mounting, Mr. Cooke possessed the great advantage of being not alone an accomplished and theoretical optician, but at the same time a mechanical engineer of no ordinary ability. Thus he seems to have been the first person to apply the ordinary means and machinery of mechanical engineering to the construction of optical instruments, treating them as accurate machines rather than as delicate instruments to be constructed solely by the hand. He made his own tools, and for the most part cast his own brass.

During the last five or six years of his life, Mr. Cooke turned his attention to the subject of circular graduation, and, after studying all the best existing machines for executing that most delicate kind of work, constructed for his own use a self-acting dividing engine of nearly 3-feet diameter. In this beautiful machine there are many novelties; the all-important process for ratching the edge of the main circle, the form of the vertical axis on which it revolves, the means of centring the circle to be operated on, and the gear for working the cutting tool, all differing from anything hitherto similarly employed, exhibit innumerable examples of Mr. Cooke's sound mechanical knowledge prompted by his rare fertility of invention. A larger machine, more perfect still, and capable of dividing circles of 4-feet in diameter, was designed and in part constructed by him, but its completion devolves on his successors. The self-acting engine formed part of the plant necessary to enable Mr. Cooke to carry out, under his own eye, the considerable orders for theodolites and other surveying instruments which latterly were given him by the Indian Government. Into this class of instruments he introduced many valuable improvements, and the workmanship which he bestowed on them, as on every thing that came from his hands, has rarely been equalled—never excelled.

Mr. Cooke was a horologist of no mean pretensions. Nearly one hundred turret-clocks, erected in churches and public institutions in all parts of England, testify by the accuracy of their performance to the exactness of their maker's mind. He brought to great perfection astronomical clocks, not only those of the ordinary kind, but also clocks exhibiting, under the regulation of a single pendulum, both sidereal and solar time on the same dial.

There was in Mr. Cooke's temperament no small admixture of the artistic element; a certain grace of form and harmony of proportion will be found to characterise all his works,—ennobling, by beautifying, the structure reared on rigid principles. Nor was he indifferent to the convenience of the too often forgotten observer. He was the first to employ, on the suggestion of his friend Lieut.-Col. Strange, machinery for engraving the

figures on his instruments. By means of a small and simple engine the entire figures, of a standard form of maximum visibility, are engraved on a circle in less than two hours by an ordinary mechanic, with an elegance and precision unattainable by the most skilful unaided hand.

The first important meridional instruments made by Mr. Cooke were a pair of 5-feet transits destined to be employed in the determination of longitude by the officers of the Great Trigonometrical Survey of India. These are probably the largest portable instruments of their class in existence; and in some other respects they are unique. The transit axis are of aluminium bronze, an alloy selected for its immense rigidity; the appliances for effecting the principal adjustments are peculiar; and the mode in which no less than four levels are employed for effecting and watching the horizontality of the axis, and for determining its variations of flexure for different altitudes, contrived exclusively by Mr. Cooke, involves principles and presents features worthy of imitation. These fine instruments are briefly described by Lieut.-Col. A. Strange, under whose superintendence they were constructed, in the *Monthly Notices* for April and May, 1865, and in the *Proceedings of the Royal Society*, No. 90, 1867.

In September, 1863, Mr. Newall, of Gateshead, gave Mr. Cooke the princely commission to construct for him the largest refracting telescope that had ever been proposed with the least probability of a successful issue; it was a gigantic equatoreal of no less than 25 inches clear aperture! At the present time we believe the largest completely mounted equatoreal does not exceed 15 French inches in aperture; the stride from even these magnificent machines to the dimensions of that undertaken by Mr. Cooke is simply enormous. The accurate figuring and polishing of such an object-glass requires an amount of skill, patience, mechanical resource, and self-reliance, of which no person not conversant with the innumerable difficulties besetting the attempt can form a conception. It may be sufficient here to say that in the present instance it was necessary to float the huge lenses of the telescope on quicksilver, lest some undue or unequal pressure during the act of polishing their surfaces should disturb their forms. There were also other mechanical contrivances of great ingenuity, which upon the final completion of the instrument, Mr. Cooke proposed to communicate to the scientific public without reserve. The object-glass was finished early in 1868, and the mounting is now nearly complete. The telescope is driven by a clock, the regulation of which is partly effected by the introduction of a pendulum escapement, producing an uniformity of motion which probably has not heretofore been obtained by other means. The description of this clock will be found in the *Monthly Notices* for 1868. The object-glass is said to be a complete success; if that on further trial prove to be the case, a work will have been accomplished which, for its magnitude and difficulty, is unexampled in the history of Astro-

nomical Instruments. A noble transit-circle of 7 inches aperture is to accompany this imperial philosophical machine.

When Troughton completed his magnificent transit instrument for the Royal Observatory at Greenwich, he inscribed his honoured name upon it with very pardonable pride ; in his days it was unique in the world, for all days it will be a noble monument of his skill. But this beautiful work of the great optician would look like a toy by the side of Cooke's gigantic equatoreal. The name of its constructor will ere long be engraved on this mighty instrument ; it may well serve as the epitaph for his tomb, for the eye of Thomas Cooke was not permitted to see the completion of the work which his own genius had devised. Worn out, partly by the days and nights of anxiety which were unavoidably incident on so vast an undertaking, and partly by the struggles which always accompany the efforts of a man who has to make his own fortunes unaided in the world, he sank to his rest on the 19th of October, 1868, in the 62nd year of his age.

For some years past the great York factory has been practically superintended by two of Mr. Cooke's sons — Mr. Thomas Cooke, the depository of his father's profound knowledge, an accomplished optician ; and Mr. Frederick Cooke, a mechanician of the highest attainments. The traditions and the methods of the house are in safe hands,— in the hands of those who will spare no effort to maintain and augment the fame which has become their most valued inheritance.

Those who had the advantage of knowing Thomas Cooke could not fail to admire him for his attainments and his genius ; for the genuine truthfulness and simplicity of his character he won their love. Unlike most self-educated men, he was singularly modest in the appreciation of his own powers ; unlike many men who have had long to struggle for eminence in their profession, he was singularly free from the depreciation of the abilities of his rivals. The foundation of his future skill as an optician he had laid in early life by a diligent application to mathematical studies, and it was impossible for any competent person to converse with him on the subject of his favourite science without being struck with his profound knowledge of every branch of its theory, while it was evident that he had put that theory to the test, and in some important instances had improved it by his experiments. It was owing to this happy combination of theory with experiment that the late Mr. Dawes was enabled to pass his well-known and well-deserved eulogy on the peculiar character of the achromatism of his telescopes.

England has acquired a well-merited reputation for its long and unequalled succession of eminent constructors of astronomical instruments. To the great names of the past, such as Dollond, Bird, Ramsden, Troughton and Simms, we must now in gratitude add that of Thomas Cooke. Happily there are those still living among us who possess the promise and the power of emulating his fame. [C. P.]

Proceedings of various Observatories.

Royal Observatory, Greenwich.

Since the date of the last Report the principal special work at the Royal Observatory has been the reduction of the great bulk of the preparatory work for the new Seven-year Catalogue of Stars, which will contain the results of all the stellar observations made with the Transit-Circle, from 1861, January 1, to 1867, December 31. The star-constants, precessions, and secular variations, have been computed afresh for the adopted epoch (1864), and considerable progress is made in the reduction of the yearly values to the same epoch.

The addition of a labour of this kind to the ordinary office-work of the Observatory is always sufficient to absorb a large proportion of the computing-staff of the establishment. The work is, however, performed without any serious interference with the usual routine computations. It is believed that the new Catalogue will be found to be exceedingly valuable to Astronomers, for it will contain not only the positions of all the standard stars, but also those of a considerable number of stars which had never been observed at Greenwich since the time of Dr. Bradley, and which are included in Bessel's *Fundamenta Astronomiæ*. Every star observed by Bradley, whose R.A. and N.P.D. are contained in that work, has now been re-observed at Greenwich since the Observatory has been under the direction of the present Astronomer Royal. We shall have, therefore, ample materials for the determination of the proper motions of the remaining Bradley's stars not previously included in the papers of the Rev. R. Main and Mr. Stone. The Catalogue will also include stars observed for special purposes, as, for example, at the request of Colonel Sir Henry James, Director of the Ordnance Survey, and of Colonel Walker, Superintendent of the Great Trigonometrical Survey of India.

The number of stars contained in the new Catalogue will be about 2760.

During the past year, the Sun, Moon, planets, and special list-stars, have been observed as usual with the Transit-Circle; and the Moon, with accompanying stars and collimator for the instrumental corrections, with the Altazimuth. The observations with the latter instrument have been very numerous during the past summer and autumn, the number of complete observations of the Moon having far exceeded that in the corresponding period of any previous year.

The printing of the volume of the *Greenwich Observations* for 1867 is in an advanced state, and the reductions of the observations made in 1868 are nearly completed.

The transit of *Mercury* over the Sun's disk on the morning of November 5 was very successfully observed. The details of the observations are given in the *Monthly Notices*. Independently of the value of the observed times of egress, the phenomenon gave the observers an opportunity of noticing the formation of the black ligament, and of deciding the question of the reality of the existence of the *two* phenomena of real and apparent internal contacts, as explained by Mr. Stone, in his recent paper on the 'Rediscussion of the Observations of the Transit of *Venus* in 1769.'

For the express purpose of determining the heating powers of the stars, a delicate combination of a small thermo-electric pile and sensitive reflecting galvanometer has been arranged by Mr. Stone. This apparatus (Mr. Stone's private property) which was finished in 1868, December, has only been tried, on account of late unsettled weather, on two nights; and that merely sufficiently to test its applicability to the purpose for which it was arranged. There was no intention to have called public attention to the matter until quantitative results had been obtained. It now appears that Mr. Huggins had, in 1867, applied a similar arrangement to the same purpose. Under these circumstances it has been thought advisable to mention the perfect independence of Mr. Stone's work upon this subject.

Royal Observatory, Edinburgh.

The number of meteorological stations in Scotland, whose observations are computed here, remains at fifty-five, and these are still regularly prepared for and printed by the Registrar-General of Births, Deaths, &c. in Scotland, either every month, or quarter, or both.

The distribution of time to the public by time-ball, time-gun, and Jones's controlled clocks, continues as heretofore; also meridian observations of stars with Transit instruments and Mural Circle—the zero points for Right Ascension being adapted invariably from the Greenwich list of fundamental stars, both polar and equatorial, as most obligingly furnished by the Astronomer Royal, G. B. Airy, at the beginning of every year.

Radcliffe Observatory, Oxford.

No change has taken place in the organisation or subjects of observation at this Observatory during the past year. The Transit Circle has been actively employed, and the Heliometer whenever the weather would permit it, throughout the year 1868.

The state of the reductions and of the printing is kept up to pretty nearly the same state of forwardness as before, as will be shown by the following statement. All the Astronomical Observations of 1867 have been completely reduced and discussed, and

the Catalogue of Stars, containing about 1400, observed in both elements. As usual, considerable pains have been bestowed upon the discussion of the observations of N.P.D., which are on the whole very satisfactory. The transits have been reduced to the end of the year 1868, but the observations of N.P.D. are less advanced than usual, on account of the labours bestowed on the Second Radcliffe Catalogue. This is now essentially complete, and the printing of it will commence very shortly. An elaborate comparison has been made of the positions of the stars in this Catalogue with the positions of stars in the Greenwich Catalogue of 2022 stars for 1860. The varying errors of the equinox at different hours of Right Ascension are very similar to those in the First Radcliffe Catalogue; and, with regard to the N.P.D.s, the differences are small, but there is a curious law of periodical errors (the stars being arranged in order of polar distance) very similar to that exhibited in the observations made with the Carrington Transit Circle. Thus we have observations made with two distinct circles, and treated by two different astronomers, giving almost precisely the same errors when compared with the results of the Greenwich Transit Circle ; and the differences are not accounted for in any great degree by the difference of the refraction constants which are employed in the reductions.

The printing has gone on at the usual rate, that is, the results of the Astronomical Observations for 1866 have been printed for some time, and the printing of the volume for 1867 has been begun. The Meteorological Reductions for 1866 are nearly finished, and then the volume will be completed.

While speaking of the meteorology, it may be mentioned that the observations of the wind for some years have been recently discussed by Mr. Baxendell of Manchester, who has arrived at a very curious result with reference to the well-known fact of the different average velocities of the wind during the day and night hours. Observing that during the night hours, till seven o'clock in the morning, the velocity is sensibly constant, but increasing very rapidly after that hour, he finds that the force put in action to produce this additional velocity is almost precisely at right angles to the direction of the magnetic meridian; and he considers that this force, from whatever cause derived, is too large to be neglected in any speculations or forecasts of the weather.

Cambridge Observatory.

The Transit and Circle Observations during the year have been limited almost wholly to the usual observations of the Sun about the times of the equinoxes and solstices; to observations of *Jupiter*, *Uranus*, *Neptune*, and *Iris*, near the oppositions, and to the observations of fundamental stars for the determination of instrumental and clock errors. *Iris* was observed for the purpose of testing the accuracy of the Ephemeris, which Dr. Brunnow has computed by means of his new and still unpub-

lished Tables of that planet. These observations were made with great difficulty on account of the deficiency in optical power of our present meridian instruments.

The errors due to the form of the pivots of the Transit instrument have been carefully re-determined. A comparison with former determinations shows that the changes arising from the wear of the pivots are very slight.

Two very satisfactory series of observations of Brorsen's and Winnecke's Comets were taken with the Northumberland Equatoreal. The relative position and distance of *Algol* and its companion were determined at the request of Mr. Aldis.

The Equatoreal has also been used occasionally in observing occultations.

The courses of a considerable number of the August Meteors were observed by means of the two meteoroscopes.

The anemometer has been out of order more than once during the past year in consequence of the formation of ice in the interior of the box containing the wheel-work, by which the wheels have been stopped and their teeth injured. Measures have now been taken to prevent the accumulation of moisture in the interior for the future. With the exception of these interruptions in the determination of the velocity of the wind, the meteorological observations have been punctually registered.

The reductions and the preparation for the press have gone on steadily. The Transit Observations of several years are ready for the press, and part of the copy is in the printer's hands. Considerable progress has also been made in the copy for the press of the Mural Circle observations.

Nearly all the Equatorial observations of occultations and of comets made up to the present time are reduced.

The Meridian circle which Mr. Simms is constructing for this Observatory is now in a very forward state, and it is hoped that it will prove to be one of the finest instruments of its class. Preparations will shortly be made for mounting this instrument, which is to occupy the place of the present Transit instrument.

Liverpool Observatory, Bidston, Birkenhead.

An important alteration has recently been sanctioned by the Mersey Docks and Harbour Board with regard to the conditions on which chronometers are in future to be received at the Liverpool Observatory. Hitherto they have been left for an indefinite time, for the purpose of being rated, and a large amount of labour has thereby been thrown upon the observatory. In future, chronometers are to be received for such a time only as is found to be necessary for efficiently testing them. Subject to the regulations, chronometers belonging to ships paying dues to the Mersey Dock Estate are tested gratuitously, as are also those belonging to any chronometer-maker, who on application can now send such a num-

ber to be tested as the Director of the Observatory may from time to time decide upon.

As a means of communicating time to the port and towns of Liverpool and Birkenhead the time-gun is found to be very successful. The position of the gun is such that a view of the flash is commanded for several miles both up and down the river Mersey, and the sound is well heard for a long distance on each side of the river.

The work in the hands of Messrs. Troughton and Simms has been greatly delayed, and is not yet completed.

Glasgow Observatory.

The observations at the Glasgow Observatory during the past year have been essentially the same as in former years. The Transit Circle is employed in the observation of a selected list of stars below the fifth magnitude. Greenwich time continues to be transmitted to the city and port of Glasgow by Jones's method of control. An improved form of micrometer by Troughton and Simms has been recently obtained for the Ochtertyre Equatoreal, and observations of the minor planets are now made with the instrument on every favourable night. A few observations of Brorsen's Comet were obtained on the occasion of its last return to the perihelion. Professor Grant finally reports that the system of meteorological operations established by the Meteorological Committee of the Royal Society, acting in concert with the Board of Trade, is now regularly prosecuted at the Observatory.

Royal Observatory, Cape of Good Hope.

A very careful series of observations of *Mercury* on the Sun's disk were made here by Mr. Mann. A very accurate determination of the errors of the differences in the tabular places of the planet and the Sun is thus afforded.

The November Meteors were well observed. These results will shortly appear in our *Notices*.

The reductions for a Catalogue are going on unflinchingly.

Kew Observatory.

During the past year the Kew Heliograph has been at work without interruption, except from unfavourable weather.

There were on the whole 174 days of observation, on which 285 sun-pictures were taken.

The measurements alluded to in the last Report are continued with the utmost rapidity consistent with that extreme accuracy which is necessary in determining the positions of spots, and at the present moment the heliographic positions, as well as the areas of three years of sun-spots, have been determined, commencing

with February, 1862. The measurements for two of these three years are given in a paper (alluded to in the last Report), which was presented to the Royal Society on March 31st, 1868, and is entitled "Researches on Solar Physics; Heliographical Positions and Areas of Sun-spots, observed with the Kew Heliograph during the years 1862 and 1863." By Messrs. De La Rue, Stewart, and Loewy. The paper is at the present moment going through the press as part of the *Transactions of the Royal Society.*

The same authors communicated to the Royal Society in June, 1868, an account of certain observations and measurements of a spot which was fortunately photographed at Kew while in the act of passing round the Sun's limb. This paper is entitled "An Account of some recent Observations on a Sun-spot made at the Kew Observatory," and is also being printed in the *Transactions of the Royal Society.*

Besides these two papers there has been printed a short appendix to the second series of preliminary researches in Solar Physics. This paper exhibits the distribution in heliographic latitudes of the sun-spots observed by Carrington, and shows, on an average, the latitudes of sun-spots when *Venus* crosses the solar system as less than when she is at her greatest distance therefrom. It also shows that there is excessive solar action at those periods when *Venus* and *Mercury* are together, thus tending, in connexion with previous researches, to the conclusion that *Venus*, *Jupiter*, and *Mercury*, are the planets most influential as regards the production of spots.

Finally, two communications have been made to the Royal Astronomical Society; the one giving a representation of the appearance which the Sun presented at Kew on the day of the total eclipse, Aug. 18, 1868, and the other being the usual yearly comparison of the number of groups of spots observed at Kew and at Dessau during the past year.

The plan of work for the present year is, while continuing the photographic observations, to push on with the measurements; and it is hoped that before next Report the positions and areas of spots for two more years may have been made, thus comprising five years in all, from the commencement in 1862. And also that another paper, embodying these positions and areas, may have been communicated to the Royal Society.

It is also hoped that the observations on distortion may be repeated and reduced. At the present moment it is impossible to commence the series of actinic observations alluded to in last Report.

Lord Rosse's Observatory.

During the last year the observations on the nebulæ and clusters of stars in Sir John Herschel's Catalogue have been continued in the same manner as heretofore.

Lord Rosse's present assistant has on two or three occasions examined the spectrum of the Great Nebula in *Orion*, and confirms previous suspicion that there exist in it other bright lines in addition to the three well-known ones; more particularly one on the more refrangible side of F (a position where it could not be confounded with the maximum brightness of a continuous spectrum); all these lines are, however, of extreme faintness.

During this season the planet *Jupiter* has been examined, and a few sketches made.

A series of drawings of *Mars* has also lately been begun.

Some experiments on lunar radiation have been commenced, which have been so far successful as to show that the thermo-electric pile is capable of detecting heat near the time of full moon. In consequence, however, of the various disturbing causes having been only partially eliminated, as yet no reliable estimate of its amount has been made; the hope is entertained that this may be done.

Mr. Huggins' Observatory.

Time has not been found during the past year to continue some experiments which were conducted in the Observatory in the early part of 1867, for the purpose of detecting the heat received from the stars, and also, if possible, from the Moon. It may be well, however, to state that though, in consequence of the great difficulty of avoiding disturbing influences, no trustworthy quantitative estimate was obtained, yet, in the case of the stars *Sirius*, *Regulus*, *Pollux*, and *Arcturus*, the observations made in the early part of 1867 showed that the very sensitive thermopile, which had been specially constructed for these experiments, was sensibly affected. The heat of the Moon was observed with less certainty. These observations will be continued.

In the early part of 1868, observations which had been for some time in progress for the purpose of ascertaining the motion of stars towards or from the Earth by means of alterations in the refrangibility of their light, were successfully concluded for *Sirius*.* The line in the spectrum of *Sirius*, at the position of Fraunhofer's F, and due to hydrogen, was found to have been shifted by the star's motion towards the red, to an amount such as to show that *Sirius* was moving from our system with a velocity of about 29 miles per second. But this amount has to be corrected for the solar motion in space.

Similar observations on the Great Nebula in *Orion* showed that the coincidence of two of the lines of its spectrum respectively, with a line of hydrogen and a line of nitrogen, was perfectly maintained in an apparatus in which a difference of wave length of 0·0460 millionth of a millimetre would have been

* See *Philosophical Transactions*, 1868, p. 529.

detected. This nebula, therefore, was not receding with a velocity so great as 10 miles per second, for this motion added to that of the Earth would have caused a want of coincidence that would have been observed. If the nebula were approaching us, it might have had a velocity as great as 20 or 25 miles per second, as part of it would have been annulled by the Earth's motion in the opposite direction.

The method of placing the induction spark before the object-glass brought into notice a fact of some interest. The loss of brightness showed itself in the case of the spectra of hydrogen and nitrogen, by the total extinction of all the lines, with the exception of the one line in each spectrum, which is found in the nebulæ. If we should have reason to believe that lines in the nebulæ have been quenched on their way to us, we must consider it as an evidence of a power of extinction of light existing in cosmical space, and not as an effect of distance, since the nebulæ are objects of sensible size.

During the year two Comets have been subjected to prismatic examination. Brorsen's Comet gave a spectrum of three bright bands.* Comet II. 1868, gave also three luminous bands, which, though in similar parts of the spectrum, differed considerably in position and in character from those of Brorsen's Comet. The spectrum of shaded bands of Comet II. was found, by direct comparison in the instrument with the spectrum of olefiant gas, to be identical in refrangibility and in general characters with the spectrum of carbon.†

On April 15, 1868, the spectrum of a solar spot was examined. It was found that three-fourths of the apparent light of the umbra came from that region of the Sun, the remaining fourth from our atmosphere. Most of the lines were increased in width, but this was not the case with the lines C and F, which are due to hydrogen. This fact is of interest in connexion with what we now know to be the nature of the solar prominences, and may have been due to these objects lying over the umbra of the spot.

With the help of the information of the positions of the bright lines of the solar prominences, furnished by the eclipse of August 1868, these bright lines were found, at the first instant of looking for them, with a small spectroscope, with which they had been sought for previously in vain.

The appearances observed at the Transit of *Mercury* have been described in the *Monthly Notices*. For the purpose of throwing light upon the origin of the bright spot seen upon *Mercury*, an artificial disk of about the same apparent size as *Mercury* was viewed upon the Sun, but no bright spot could be detected upon it.

* *Proceedings of the Royal Society*, vol. xvi. p. 386.
† *Phil. Trans.* 1868.

Mr. Lockyer's Observatory.

Mr. Lockyer's observatory work has of late been exclusively devoted to the Sun, and his recent discoveries have been alluded to in another part of this Report.

Mr. Lockyer's detailed account of his work, communicated to the Royal Society and the Paris Academy of Sciences, includes among other matters,—

I. The determination of the exact position and number of the bright lines observed in the red flames, the phenomena which characterise them, and the substance of which they are principally composed.

II. The determination of the fact that the red flames are merely local heapings up of an envelope which is continuous round the Sun.

III. The approximate determination of the pressures existent in the prominences and at the bottom of the continuous envelope.

IV. A discussion of the bearing of these discoveries on the received theory of the physical constitution of the Sun.

Mr. Lockyer has suggested the term "Chromosphere" for the region or shell of the luminous prominences, which he has shown to completely surround the limb of the uneclipsed Sun.

At the time that the spectroscope revealed to Mr. Lockyer the fact that the prominence spectrum was never absent, and that, in fact, the prominence matter formed a continuous envelope round the Sun, he was not aware that such an envelope had been suggested by previous observers. He has since found, however, that Professor Grant * had based such a suggestion on an elaborate investigation of the eclipses up to and including that of 1842. That Mr. Swan and Herr Littrow afterwards came to the same conclusion from the eclipse of 1851; and that, later still, M. Le Verrier † and Father Secchi both published, after the eclipse of 1860, the idea that there was such a continuous envelope, which is indicated in the discussion by Mr. De La Rue of his admirable photographs.‡

The experimental proof of the truth of these surmises is, however, due to Mr. Lockyer. In his paper it is stated that, under proper instrumental and atmospheric conditions, the spectrum of the chromosphere is always visible in every part of the Sun's periphery; its height, and the dimensions and shapes of several prominences, observed at different times, are given in the paper. One prominence, 3′ high, was observed on the 20th of October, 1868. The possibility of variations in the thickness of this envelope is suggested, and the phenomena presented by the star in *Corona* are referred to.

* *History of Physical Astronomy*, chap. ix.
† *Phil. Trans.* 1862, pp. 405, 406; also Plate XV.
‡ *Cosmos*, vol. xvii. p. 174.

Mr. Lockyer also points out that the line F invariably expands (that the band of light gets wider and wider) as the Sun is approached, and that the C line and the D line do not widen; and he enlarges upon the importance of this fact, taken in connexion with the researches of Plücker, Hittorf, and Frankland, on the spectrum of hydrogen. It is in connexion with this widening out that Mr. Lockyer, in conjunction with Professor Frankland, has been already able to determine the pressure at the surfaces of the chromosphere.

The F line, in fact, appears like an arrow-head resting on the Sun, and Plücker and Hittorf have ascribed such a widening out of the green hydrogen line as is here indicated as due either to temperature or pressure. This widening out has been found to be a real curve of pressure, extending from the highest prominences down to the surface of the photosphere; and the prominences have been determined to be of the most excessive tenuity, and the base even of the chromosphere to be of very much less than the pressure of the Earth's atmosphere.

Messrs. Frankland and Lockyer suggest in their preliminary notes on the chemical extension, so to speak, of the Observatory work, that the facts and experiments seem to show that Kirchhoff's hypothesis is no longer tenable; that, in all probability, the chromosphere is the only extensive envelope, outside the photosphere, and that the region of selective absorption is either situated in the photosphere itself or extremely close to it. Further, that the photosphere is neither solid nor liquid, but gaseous; the most brilliant portions of it giving out bright lines and forming apparently an ever-varying shell—the tops of smaller convection currents carrying matters out of the more intensely absorptive region indicated by Mr. Lockyer in a paper communicated to the Royal Society in 1866.

Notices of some points of Interest connected with the Progress of Astronomy during the past Year.

Solar Eclipse of 1868, *August* 18.

The results obtained by the different observers are of such interest and importance that the principal observations which would not otherwise appear in our Transactions are given in considerable detail in the observers' own words.

It is with great satisfaction that the Council call the attention of the Fellows of the Society to the complete success of their own expedition;—a success for which the Fellows are much indebted to the skill and energy of the Superintendent, Major Tennant.

The Astronomical Society's Expedition.

It will be in the recollection of our Fellows that at the last Anniversary Meeting it was stated that preparations had been made at the recommendation of the Council of our Society for the observation of the Total Eclipse of the Sun in India. The Astronomer Royal took a warm interest in the proposed observations, and addressed the Secretary of State for India on the subject. It was ultimately arranged that the expense of the expedition should be borne jointly by the Government of India and the Imperial Government. The superintendence of the expedition was intrusted to Major Tennant. It is with great satisfaction that the Council is able to announce that Major Tennant has been most deservedly and eminently successful.

The Report of Major Tennant's observations is now in the hands of the Society, and it is intended that it shall appear in the forthcoming volume of the *Transactions*, fully illustrated with facsimiles of the photographs taken at Guntoor, which it is proposed to enlarge photographically, in order that the details of the prominences may be seen more clearly than is possible in the small copies which accompany the paper. Mr. De La Rue, who evinced considerable interest in the expedition and afforded facilities to Major Tennant for familiarising himself with astronomical photography before he started, has undertaken to see that the photographs are properly enlarged and copied.

It is here proper to state that to Major Tennant is due the credit of having first called attention to the peculiarly favourable conditions which would be presented by the Solar Eclipse of August 1868.*

It is only justice also to mention that, as far as regards the part which England took in the observations, it was mainly attributable to the energetic, active, and untiring zeal of Major Tennant, who happened to be in England on leave during the greater part of 1867, and who devoted much time in promoting the observations which, in spite of many difficulties, have been so successfully undertaken and carried out.

It will be recollected that Major Tennant, after consulting with the Astronomer Royal and other Fellows of the Society, undertook the following work. It was most comprehensive, and entailed possibly almost too much responsibility for the director of a single expedition.

1st. The determination of the geographical position of the station. This was successfully accomplished by means of a repeating-circle, although, in consequence of bad weather, there were not many available days between the arrival of the observers and instruments at Guntoor and the day of the eclipse. The position was found to be, Latitude N. $16^{\circ}\ 17'\ 29''{\cdot}23$, and Longitude E. $5^{h}\ 21^{m}\ 48^{s}{\cdot}6$.

* *Monthly Notices*, vol. xxvii. pp. 79, 174.

Captain Branfill, R.E., subsequently connected the station with the marks of the Great Trigonometrical Survey, and deduced the following result: Lat. N. 16° 17′ 34″·3, and Long. E. $5^h\ 21^m\ 46^s{\cdot}5$.

2nd. Spectroscopic Observations. These were undertaken by Major Tennant himself, by means of the Sheepshanks' equatoreal, of 4·6 inch aperture and 5 feet focal length. This had been mounted equatoreally by the late Mr. Cooke, and was suitable for all latitudes in the British Isles, but it had to be altered to suit the more southern stations of India. The spectroscope employed with the telescope was made by Messrs. Troughton and Simms, and was provided with a scale of equal parts, which was illuminated by means of a lamp. The addition of this spectroscope threw additional work on the driving clock beyond that for which it was originally calculated, and, in consequence, some difficulties were experienced just at the critical time of observation from the irregularity of its going.

In spite, however, of this and other mishaps Major Tennant was able to carry out his observations, and ascertained, 1st, that the corona only gave the continuous solar spectrum. 2nd, that the light of the prominences was resolvable into certain bright lines of definite refrangibility, showing that these appendages consist of gaseous matter at a very high temperature. Major Tennant states that the Great Horn gave a beautiful line in the red, a line in the orange, and one in the green, which appeared multiple, also a line seen with difficulty near F; he says the red and yellow lines were evidently C and D, the reading of the bright line coincides with that of the brightest line in *b*. The line near to F was, in all probability, F itself; E, he says, was certainly not seen by him, and that, as regards the line in the blue, it was useless from his data to speculate upon it.

We now have more precise information from the researches of M. Janssen and Mr. Lockyer respecting the position of the bright lines, and the probable nature of the Sun's appendages; but it must be admitted that Major Tennant did this part of his work well, especially when the scope of the instruments at disposal is taken into account.

3rd. Major Tennant noted the time of first contact of the Sun and Moon's limbs by means of the repeating-circle at $6^h\ 2^m\ 12^s{\cdot}60$, sidereal time, and that of the last contact at $8^h\ 47^m\ 24^s{\cdot}62$, sidereal time.

4th. Polariscope. This part of the work was most ably performed by Captain Branfill, who joined Major Tennant early in August, and immediately set to work to familiarise himself with the phenomena produced by polarised light in the telescope. This instrument was one of the old collimators of the Great Transit Circle of Greenwich, and was lent by the Astronomer Royal. It was mounted on a polar axis, so that with one movement it could be made to follow the apparent motion of the Sun, but it was not provided with a driving-clock. To this telescope

a polariscope eye-piece had been fitted by Mr. Ladd. The polarising apparatus comprised several combinations which could readily and rapidly be substituted one for the other. All these concurred in showing that the prominences (the Great Horn was chiefly observed) gave no indication of polarised light; on the other hand, every arrangement brought out the fact that the light of the corona was polarised in a plane passing through the Sun's centre. These observations were therefore fully and successfully carried out, and left nothing to desire.

5th. We now come to the photographic observations; these were under the immediate direction of Sergeant Phillips, who is not only a skilled photographer, but also had the advantage (as well as the Sappers who aided him) of working in Mr. Warren De La Rue's observatory at Cranford. The telescope employed is a Newtonian with a silvered-glass mirror, 9 inches in diameter. by With, and specially mounted by Mr. Browning. Preparations had been made for having a very large field, in order that the corona might be depicted as well as the prominences. Unfortunately the Sun was covered with cumulo-stratus clouds which diminished the actinic power of the light of the corona so much that it was not recorded. In other respects the photographs (six in number) were eminently successful.

Interval.					
			h m s		
s	No. 1	Exposed at	7 17 2·9	S. T. for	1ˢ
58·5					
61·4	„ 2	„	18 1·4	„	5ˢ
58·1	„ 3	„	19 2·8	„	10ˢ
63·2	„ 4	„	20 0·9	„	5ˢ
90·7	„ 5	„	21 4·1	„	1ˢ
	„ 6	„	7 22 34·8	„	1ˢ

Paper copies of these, about 2 inches in diameter, accompany the Report; and Mr. James, one of Major Tennant's assistants, made excellent drawings of the Great Horn and other prominences seen in the photograph, by means of the microscope. Since the arrival of the memoir, Serjeant Phillips has brought safely to England eight sets of transparent copies on glass, which have been distributed to individuals and learned bodies; amongst others, to the Royal Society and the French Academy of Sciences. On the occasion of a lecture given by Prof. Herschel, at the Royal Institution, on January 22, these were shown by means of the electric lamp, and projected on a screen, on a scale of about 5 feet for the Moon's diameter. The amount of detail visible under these circumstances was very remarkable. The spiral structure of the Great Horn, to which Major Tennant has called attention, was very evident. This spiral formation Major Tennant ascribes to the confliction of an ascending current, and one at right angles to it. Since then Mr. Warren De La Rue has

procured some very beautiful copies, about $6\frac{1}{2}$ inches diameter. He has also discussed, graphically, the small paper photographs, and communicated the results to the Society.* The diagram accompanying his paper shows fairly the form and relative position of these appendages with respect to the Sun. Mr. Warren De La Rue thought that he had detected a rotation of the Great Horn on its axis during the intervals between occurrence of totality at the various stations along the line of the eclipse. He has since been favoured by Prof. Foerster, Director of the Berlin Observatory, with a copy of the first Aden photograph, and informs the Council that there does not appear to be any very great change in the appearance of the Great Horn at Aden and at Guntoor. This comparison of results brings out forcibly the great value of photography for this class of observations, for the most careful and collected observer is liable to make an error in recording eye-observations.

In justice, however, to Col. Addison, whom Major Tennant had induced to make observations at Aden, it must be stated that a drawing of the prominences which he sent to Major Tennant led that gentleman to conclude that no change had occurred in them between the epoch of Aden and that of Guntoor.

Major Tennant reached Aden on the 25th of January; as this was nearly the first place where observations of the totality could be made, he enlisted the services of Captain Davis, the Peninsular and Oriental Company's agent, and of an old companion, Major Napier, R.A. Both these gentlemen promised their aid, and he learnt from them that Col. Addison and Major Weir, H. M. 2nd Royal Regiment, would be likely to be valuable coadjutors. Unfortunately, the contemplated observations with the polariscope, spectroscope, and intended drawings of the corona, were rendered impossible, in consequence of clouds. But the prominences were seen and recorded with great accuracy, as it has been before stated.

The Council have every reason to feel satisfied with the steps they took in conjunction with the Astronomer Royal, in furthering Major Tennant's views, and in thus securing a most valuable series of observations.

Lieut. J. Herschel's Account. Position, Jamkandi.

The totality commenced unseen. "A few seconds more and the spectrum of diffuse light vanished also, and told me the eclipse was total, but behind a cloud. I went to the finder, removed the dark glass, and waited, how long I cannot say, perhaps half a minute. Soon the cloud hurried over, following the Moon's direction, and therefore revealing, first, the upper limb, with its scintillating corona, and then the lower. Instantly I marked a

* *Monthly Notices*, vol. xxix. p. 73.

prominence near the needle-point, an object so conspicuous that I felt there was no need to take any precautions to secure identification. It was a long finger-like projection from the (real) lower left-hand portion of the circumference. A rapid turn of the declination-screw covered it with the needle-point, and in another instant I was at the spectroscope. A single glance, and the problem was solved.

"*Its Spectrum.*—Three vivid lines, red, orange, blue; no others, and no trace of a continuous spectrum.

"When I say the problem was solved, I am, of course, using language suited only to the excitement of the moment! It was still very far from solved, and I lost no time in applying myself to measurement. And here I hesitate, for the measurement was not effected with anything like the ease and certainty which ought to have been exhibited. Much may be attributed to haste and unsteadiness of hand, still more to the natural difficulty of measuring intermittent glimpses; but I am bound to confess that these causes were supplemented by a failure less excusable. I have no idea how those five minutes passed so quickly! Clouds were evidently passing continually, for the lines were only visible at intervals—not for one half the time certainly—and not always bright, but still I ought to have measured them all. My failure was in insufficient illuminating power, but why, I cannot tell. I never experienced any difficulty of the kind with the nebulæ, which required that I should flash in light suddenly over and over again. I had found the hand-lamp the surest way, but it failed me here in great measure. The red line must have been less vivid than the orange, for after a short attempt to measure it, I passed on to secure the latter. In this I succeeded to my satisfaction, and accordingly tried for the blue line. Here I was not so successful. The glimpses of light were rarer and feebler, the line itself growing shorter, and what remained of it further from the cross. I did, however, place the cross wires in a position certainly very near the true one, and got a reading before the re-illumination of the field told me that the Sun had reappeared on the other limb. These readings were called out, as those of the solar lines had been, to my recorder, and it was only afterwards that I compared them.

"I need not dwell on the feelings of distress and disappointment which I experienced on realizing the fact that the long-anticipated opportunity was gone, and, as it seemed to me then, *wasted*. I seemed to have failed entirely. Almost mechanically I directed the telescope to the bright limb, to verify the readings of the solar lines, and in doing so my interest was again awakened by the near coincidence, as it seemed, of the line F with the position of the wires; but a little reflection convinced me that the distance of the former was greater than the error which I might have made in intersecting the blue line. I read F, and then D and C. The following were my readings up and down:—

	C	D	*b*	F
Before	1·91	2·96	4·58	5·64
	1·90	2 94	4·56	5·61
	1·93	2·98	4·60	5·65
	1·92	2·97	4·58	5·62
Bright lines		[3·00]		[5·56]
After	1·93	3·00		5·65

"I consider that there can be no question that the orange line was identical with D, so far as the capacity of the instrument to establish any such identity is concerned. I also consider that the identity of the blue line with F is not established; on the contrary, I believe that the former is less refracted than F, but not much. With regard to the red line, I hesitate very much in assigning an approximate place; B and C represent the limits, it might have been near C; I doubt it being so far as B. I am not prepared to hazard any more definite opinion about it. Its colour was a bright red. This estimate of its place is absolutely free from any reference to the origin of the lines C and F."

The spectrum of the corona does not appear to have been specially examined.

Lieut. Campbell's Report.

"The instruments in question were as follows: a telescope of 3-inch aperture, mounted on a rough double axis, admitting of motions in azimuth and altitude by hand only unaided by any appliance for clamping and slow motion. The telescope was provided with three eye-pieces of magnifying powers 27, 41, and 98; and with it were furnished two analysers for polarized light, viz., a double-image prism and a Savart's polariscope.

"On the first opportunity after the commencement of the total phase of the eclipse I turned on the double-image prism with the eye-piece of 27 magnifying power, as recommended in the Instructions, which gave a field of about 45′ diameter. A most decided difference of colour was at once apparent between the two images of the corona; but I could not make certain of any such difference in the case of a remarkable horn-like protuberance, of a bright red colour, situated about 210 degrees from the vertex, reckoned (as I have done in all cases) with reference to the actual, not the inverted image, and with direct motion. I then removed the double-image prism and applied Savart's polariscope, which gave bands at right angles to a tangent to the limb, distinct, but not bright, and with little, if any, appearance of colour. On turning the polariscope in its cell, the bands, instead of appearing to revolve on their own centre, passing through various phases of brightness, arrangement, &c. travelled bodily along the limb, always at right angles thereto, and without much change in intensity, or any at all in arrange-

ment. The point at which they seemed strongest was about 140° from the vertex, and I recorded them as black centred. Believing that with a higher power and a smaller field I should find it easier to fix my attention on one point of the corona, and observe the phases of the bands at that point, I changed eye-pieces, applying that of 41 power. With this eye-piece the first clear instant showed the bands much brighter than before, coloured, and as tangents to the limb at a point about 200° from the vertex: but before I could determine anything further a cloud shut out the view, and a few seconds later a sudden rush of light told that the totality was over, though it was difficult to believe that five minutes had flown by since its commencement. I experienced a strong feeling of disappointment and want of success: the only points on which I can speak with any confidence being as follows:—

"(1.) When using the double-image prism, the strong difference of colour of the two images of the corona, and the absence of such difference in the case of the most prominent red flame. (2.) With Savart's polariscope the bands from the corona were decided: with a low power they were wanting in intensity and colour: excepting alternate black and white, making it difficult to specify the nature of the centre: and their position was at right angles to the limb, extending over about 30° of the circumference. When the polariscope was turned the bands travelled bodily round the limb without other changes in position or arrangement, as if, indeed, they were revolving round the centre of the Sun as an axis. With a higher power, when a smaller portion of the corona was embraced, the bands were brighter coloured, and seen in a different position, viz., tangents to the limb.

"The appearance observed with a low power seems exactly what might be expected supposing the bands to be brightest at every point when at right angles to the limb, in which case the bands growing into brightness at each succeeding point of the limb, would distract attention from those fading away at the points passed over as the analyzer revolved."

Rapport de M. Rayet.

"L'appareil dont je me suis servi à Wah-Tonne, pour l'examen optique de la lumière des protubérances, se composait d'un télescope à miroir de verre argenté, de 20 centimètres de diamètre, monté équatorialement pour la latitude de la station, et d'un spectroscope à vision directe. Ce dernier instrument, formé de trois prismes très-dispersifs, était combiné pour avoir une faible longueur et donner beaucoup de lumière.

"Spectre des cornes.—La fente du spectroscope ayant été orientée de manière à couper à angle droit l'image du croissant lumineux très-étroit qui devait rester quelques secondes avant l'obscurité totale, j'ai d'abord étudié la lumière de l'extrémité des

cornes. Sur le fond d'un spectre à raies obscures très-nettes, formé par la lumière atmosphérique diffuse, on voyait une bande beaucoup plus lumineuse, qui était le spectre de la lumière émise par l'extrémité de la corne. Quelque fût le peu de hauteur de cette partie on n'y distinguait rien de particulier. Les raies avaient un aspect (largeur et degré d'intensité) identique à celui des raies du spectre solaire ordinaire.

" L'observation des cornes a toutefois été interrompue quelques secondes avant l'éclipse totale, afin d'enlever les diaphragmes mis au téléscope, d'ouvrir légèrement la fente du spectroscope et d'être ainsi préparé à l'examen des protubérances.

" Spectre des Protubérances.— Dès l'instant de l'obscurité totale, la fente du spectroscope ayant été portée sur l'image de la longue protubérance qui venait de se montrer sur le bord oriental du Soleil, je vis immédiatement une série de neuf lignes brillantes, qui, d'après leur disposition dans le champ, leur espacement relatif, leur couleur et enfin par la physionomie même de leur ensemble, me semblent devoir être assimilées aux lignes principales du spectre solaire, B, D, E, *b*, une ligne inconnue, F, et deux lignes du groupe G. Ces lignes présentaient un très-grand éclat, et se détachaient vivement sur un fond gris cendré très-pâle.

" Les protubérances sont donc des jets d'une matière gazeuse incandescente, les flammes d'un phénomène chimique d'une puissance extrême. Il faut aussi remarquer que la lumière de la couronne est très-faible par rapport à celle des protubérances ; car, tandis que la lumière de ces dernières donnait un spectre très-vif, la première, malgré l'ouverture assez grande de la fente, ne donnait aucun spectre coloré sensible.

" Pendant les observations précédentes, la fente du spectroscope était parallèle à la grande longueur de la protubérance ; aussi voyait-on dans l'appareil des lignes lumineuses d'une hauteur sensible, en relation directe avec la hauteur de la protubérance. La fente ayant été tournée de 90 degrés, les raies se sont trouvées réduites à l'apparence de points brillants répondant à la faible largeur de la corne lumineuse. Il n'y a donc pas d'erreur d'observation possible, les lignes brillantes représentent bien le spectre de la lumière des protubérances.

" Le spectroscope étant dans la première position (fente parallèle à la longueur de la protubérance), les lignes très-vives, assimilées à D, E, et F, se prolongeaient au delà de la longueur moyenne par un trait lumineux très-faible ; le spectre présentait l'apparence reproduite dans le dessin ci-joint. Une certaine portion de la matière gazeuse incandescente qui forme les pro-

tubérances se répand donc dans l'atmosphère solaire au delà des limites que l'œil assigne en général à ces expansions.

" L'examen de cette première protubérance étant terminé, j'ai mis la fente sur la grande région lumineuse qui était à l'occident du Soleil. Le spectre s'est, cette fois encore, montré formé des lignes brillantes, disposées comme dans le premier cas, seulement je n'ai vu qu'une seule ligne violette. Toutes les protubérances ne semblent donc point émettre une lumière identique.

" M. Hall, ingénieur-hydrographe de la Marine de Saïgon, qui observait en un autre point de notre station, a également constaté que le spectre des protubérances était formé des lignes brillantes."

Rapport de M. Janssen.

" *Première partie.*—Le paquebot des Messageries impériales qui m'amenait de France m'a débarqué à Madras, le 16 Juillet, sur la côte de Coromandel.

" A Madras, j'ai été reçu par les autorités anglaises avec une grande courtoisie. Lord Napier, gouverneur de la province de Madras, me fit conduire à Masulipatam, sur un vapeur de l'Etat. M. Graham, collecteur adjoint, fut attaché à ma mission pour aplanir toutes les difficultés que je pourrais rencontrer dans l'intérieur.

" Il me restait à choisir ma station.

" Si on jette les yeux sur une carte de l'éclipse, on voit que la ligne de la centralité, après avoir traversé le golfe du Bengale, pénètre sur la côte Est du continent Indien à la hauteur de Masulipatam ; elle coupe les bouches de la Kistna, traverse de grandes plaines formées par le delta de ce fleuve et s'engage ensuite dans un pays élevé, contenant plusieurs chaînes situées à la frontière de l'Etat indépendant du Nizam.

" D'après l'ensemble des informations très-nombreuses recueillies et discutées, je fus conduit à choisir la ville de Guntoor, placée sur la ligne centrale à égale distance des montagnes et de la mer; j'évitais ainsi les brumes marines très-fréquentes à Masulipatam, et les nuages qui couronnent souvent les pics élevés.

" Guntoor est une ville indienne assez importante, centre d'un grand commerce de cotons. Ces cotons viennent en majeure partie des Etats du Nizam, et passent en Europe par les ports de Cocanada et Masulipatam. Plusieurs familles de négociants français résident à Guntoor ; elles descendent, pour la plupart, de ces anciennes et nombreuses familles qui, au siècle passé, faisaient fleurir nos belles colonies de l'Inde.

" Mon observatoire fut établi chez M. Jules Lefaucheur, qui voulut bien mettre à ma disposition tout le premier étage de sa maison, la plus élevée et la mieux située de Guntoor. Les pièces de ce premier étage communiquaient avec une large terrasse sur laquelle je fis élever une construction provisoire répondant aux exigences de nos observations.

"Mes instruments consistaient en plusieurs grandes lunettes de 6 pouces d'ouverture et un télescope Foucault de 21 centimètres de diamètre.*

"Les lunettes étaient montées sur un même plateau qui les rendait solidaires. Le mouvement général était communiqué par un mécanisme construit par MM. Brunner frères, qui permettait de suivre le Soleil par un simple mouvement de rappel. L'appareil était muni de chercheurs de 2 pouces et $2\frac{3}{4}$ pouces d'ouverture formant eux-mêmes de bonnes lunettes astronomiques.

"En analyse spectrale céleste, les chercheurs ont une importance toute particulière; c'est par leur intermédiaire qu'on sait sur quel point précis de l'objet étudié se trouve la fente du spectroscope de la lunette principale. Il importe donc que les fils reticulaires, ou en général les points de repère placés dans le champ du chercheur, soient réglés très-rigoureusement sur la fente de l'appareil spectral. Tous mes soins avaient été apportés pour atteindre ce but capital. Des micromètres spéciaux devaient permettre, en outre, de mesurer rapidement la hauteur et l'angle de position des protubérances. Quant aux spectroscopes adaptés aux grandes lunettes, je les avais choisis de pouvoirs optiques différents, afin de pouvoir répondre aux diverses exigences des phénomènes de l'éclipse. Enfin, tout l'appareil † portait, du côté des oculaires, des écrans en toile noire formant chambre obscure, et destinés à conserver à la vue toute sa sensibilité.

"Indépendamment de ces instruments, consacrés à l'observation principale, j'avais apporté une riche collection de thermomètres d'une grande sensibilité, construits avec talent par M. Baudin,‡ des lunettes portatives, des hygromètres, baromètres, etc. Aussi ai-je pu utiliser le bon vouloir de MM. Jules, Arthur et Guillaume Lefaucheur, que se mirent à ma disposition pour les observations secondaires. M. Jules Lefaucheur, exercé au maniement du crayon, se chargea du dessin de l'éclipse. Une excellente lunette de 3 pouces, munie de réticules, fut mise à sa disposition; il s'en servit d'avance et s'exerça, sur des représentations artificielles d'éclipses, à reproduire d'une manière rapide et sûre les phénomènes qu'il aurait à représenter. La mesure des températures fut confiée à M. Arthur Lefaucheur, qui devait aussi au moment de la totalité, par une expérience très-simple de photométrie, nous faire connaître le pouvoir lumineux des protubérances et de l'auréole.

"J'étais assisté dans mes observations propres par M. Rédier, jeune aspirant au grade d'officier, que M. le commandant du

* "Le miroir de ce télescope avait été parabolisé par M. Martin, qui a voulu donner un concours désintéresse à notre expédition."

† "MM. Bardou et Secretan m'avaient obligeamment prêté deux des quatre objectifs de 6 pouces que j'avais avec moi. M. Bardou m'avait fourni la majeure partie des instruments de cet appareil. Je citerai aussi M. Wentzel pour le talent qu'il montre chaque jour dans le travail de mes prismes."

‡ "Parmi ces thermomètres s'en trouvait un construit sur mes indications par M. Baudin, sur le plan des thermomètres différentiels de M. Walferdin, mais dont le réservoir n'avait pas plus de 1 millimètre de diamètre."

paquebot *l'Impératrice* avait bien voulu mettre à ma disposition. Le concours de M. Rédier, doué d'ailleurs dispositions heureuses pour les sciences d'observation, m'a été fort utile.

"Le temps qui nous resta avant l'éclipse fut employé à des études et des répétitions préliminaires; elles eurent l'avantage de familiariser tout le monde avec le maniement des instruments et me fournirent l'occasion de nombreux perfectionnements de détail.

"L'éclipse approchait et le temps ne semblait pas devoir nous favoriser. Il pleuvait depuis longtemps sur toute la côte. On considérait ces pluies comme exceptionnelles. Bien heureusement le temps se remit peu à peu avant le 18. Le jour de l'éclipse, le Soleil brilla dès son lever, bien qu'il fût encore dans une couche de vapeurs; il s'en dégagea bientôt, et au moment où nos lunettes nous signalaient le commencement de l'éclipse, il brillait de tout son éclat.

"Chacun était à son poste. Les observations commencèrent immédiatement.

"Pendant les premières phases, quelques légères vapeurs vinrent passer sur le Soleil; elles nuisirent à la netteté des mesures thermométriques; mais quand le moment de la totalité approcha, le ciel reprit une pureté suffisante.

"Cependant la lumière baissait visiblement; les objets semblaient éclairés par un clair de Lune. L'instant décisif approchait, et on l'attendait avec une certaine anxiété: cette anxiété n'ôtait rien à nos facultés, elle les surexcitait plutôt; et d'ailleurs elle se trouvait bien justifiée, et par la grandeur du phénomène que la nature nous préparait, et par le sentiment que les fruits de longs préparatifs et d'un grand voyage allaient dépendre d'une observation de quelques instants.

"Bientôt le disque solaire se trouve réduit à une mince faucille lumineuse. On redouble d'attention. Les fentes spectrales de l'appareil des 6 pouces sont rigoureusement tenues en contact avec la portion du limbe lunaire, que va éteindre les derniers rayons solaires de manière que ces fentes soient amenées par la Lune elle-même dans les plus basses régions de l'atmosphère solaire quand les deux disques seront tangents.

"L'obscurité a lieu tout à coup, et les phénomènes spectraux changent aussitôt d'une manière bien remarquable.

"Deux spectres formés de cinq ou six lignes très-brillants, rouge, jaune, verte, bleue, violette, occupent le champ spectral et remplacent l'image prismatique solaire qui vient de disparaître. Ces spectres, hauts d'environ 1 minute, se correspondent raie pour raie; ils sont séparés par un espace obscur où je ne distingue aucune raie brillante sensible.

"Le chercheur montre que ces deux spectres sont dus à deux magnifiques protubérances qui brillent maintenant à droite et à gauche de la ligne des contacts où vient d'avoir lieu l'extinction. L'une d'elles surtout, celle de gauche, est d'un hauteur de plus de 3 minutes; elle rappelle la flamme d'un feu de forge sortant

avec force des ouvertures du combustible, poussée par la violence du vent. La protubérance de droite (bord occidental) présente l'apparence d'un massif de montagnes neigeuses dont la base reposerait sur le limbe de la Lune et qui seraient éclairées par un Soleil couchant. Ces apparences ont été décrites avec soin par M. Jules Lefaucheur; je ferai seulement remarquer, avant de quitter le sujet des protubérances sur lequel j'aurai à revenir d'une manière spéciale, que l'observation précédente montre immédiatement:

"1°. La nature gazeuse des protubérances (raies spectrales brillantes);

"2°. La similitude générale de leur composition chimique (spectres se correspondant raie pour raie);

"3°. Leur espèce chimique (les raies rouge et bleue de leur spectre n'étaient autres que les raies C et F du spectre solaire caractérisant, comme on sait, le gaz hydrogène).

"Je reviens maintenant à l'espace obscur qui séparait les deux spectres protubérantiels. On se rappelle qu'au moment de l'obscurité totale les fentes spectrales étaient tangentes aux deux disques solaire et lunaire; elles traversaient donc les régions circumsolaires immédiatement en contact avec la photosphère, régions où la théorie de M. Kirchhoff place l'atmosphère de vapeurs qui produisent par absorption élective les raies obscures du spectre solaire. Cette atmosphère de vapeurs, quand elle brille de sa lumière propre, doit, suivant la même théorie, donner le spectre solaire renversé, c'est-à-dire uniquement formé de raies brillantes. C'est le phénomène que nous attendions, ou du moins que nous cherchions à vérifier, et c'est pour rendre cette vérification décisive que j'avais accumulé tant de précautions. Mais on vient de voir que les protubérances seules donnèrent des spectres positifs ou à raies brillantes. Or, il est bien constaté que si une atmosphère formée de vapeurs de tous les corps qu'on a reconnus dans le Soleil existait réellement autour de la photosphère, elle eût donné un spectre au moins aussi brillant que celui des protubérances, formées de gaz beaucoup plus subtils et dès lors moins lumineux. Il faut donc admettre, ou que cette atmosphère n'existe pas, ou que sa hauteur est si faible qu'elle a échappé aux observations.

"Je dois dire, au reste, que ce résultat m'a peu surpris. Mes études sur le spectre solaire m'avaient amené à douter de la réalité d'une importante atmosphère autour du Soleil, et je suis de plus en plus porté à admettre que les phénomènes d'absorption élective rejetés par le grand physicien d'Heidelberg dans une atmosphère extérieure au Soleil ont lieu au sein même de la photosphère, dans les vapeurs où nagent les particules solides et liquides des nuages photosphériques. Cette manière de voir serait non-seulement en harmonie avec la belle théorie que nous devons à M. Faye sur la constitution de la photosphère, mais il semble même qu'elle en découle d'une manière nécessaire.

"En résumé, l'éclipse du 18 août a montré, suivant moi, que la constitution du spectre solaire est insuffisamment expliquée par

la théorie admise jusqu'ici, et c'est dans le sens indiqué ci-dessus que je propose de le réviser.

" *Deuxième partie.* —Je reviens maintenant aux protubérances. Pendant l'obscurité totale, je fus frappé du vif éclat des raies protubérantielles : la pensée me vint aussitôt qu'il serait possible de les voir en dehors des éclipses; malheureusement le temps qui se couvrit après le dernier contact ne me permet de rien tenter pour ce jour-là. Pendant la nuit, la méthode et ses moyens d'exécution se formulèrent nettement dans mon esprit. Le lendemain 19, levé à 3 heures du matin, je fis tout disposer pour les nouvelles observations.

" Le Soleil se leva très-beau; aussitôt qu'il fut dégagé des plus basses vapeurs de l'horizon, je commençai à l'explorer. Voici comment je procédai. Par le moyen du chercheur de ma grande lunette, je plaçai la fente du spectroscope sur le bord du disque solaire dans les régions mêmes où la veille j'avais observé les protubérances lumineuses. Cette fente placée en partie sur le disque solaire et en partie en dehors donnait, par conséquent, deux spectres, celui du Soleil et celui de la région protubérantielle. L'éclat du spectre solaire était une grande difficulté ; je la tournai en masquant dans le spectre solaire le jaune, le vert et le bleu, les portions les plus brillantes. Toute mon attention était dirigée sur la ligne C, obscure pour le Soleil, brillante pour la protubérance, et qui, repondant à une partie moins lumineuse du spectre, devait être beaucoup plus facilement perceptible.

" J'étais depuis peu de temps à étudier la région protubérantielle du bord occidental, quand j'aperçus tout à coup une petite raie rouge, brillante, de 1 à 2 minutes de hauteur, formant le prolongement rigoureux de la raie obscure C du spectre solaire. En faisant mouvoir la fente du spectroscope de manière à balayer méthodiquement la région que j'explorais, cette ligne persistait, mais elle se modifiait dans sa longueur et dans l'éclat de ses diverses parties, accusant ainsi une grande variabilité dans la hauteur et dans le pouvoir lumineux des diverses régions de la protubérance.

" Cette exploration fut reprise à trois reprises différentes et toujours la ligne brillante apparut dans les mêmes circonstances. M. Rédier, qui m'assistait avec beaucoup de zèle dans cette recherche, la vit comme moi, et bientôt nous pûmes même en prédire l'apparition par la seule connaissance des régions explorées. Peu après je constatai que la raie brillante F se montrait en même temps que C.

" Dans l'après-midi, je revins encore à la région étudiée le matin; les lignes brillantes s'y montrèrent de nouveau, mais elles accusaient de grands changements dans la distribution de la matière protubérancielle ; les lignes se fractionnaient quelquefois en tronçons isolés qui ne se réunissaient pas à la ligne principale, malgré des déplacements de la fente d'exploration. Ce fait indiquait l'existence de nuages isolés qui s'étaient formés depuis le matin. Dans la région de la grande protubérance je trouvai

quelques lignes brillantes, mais leur longueur et leur distribution accusaient, là aussi, de grands changements.

"Ainsi se trouvait démontrée la possibilité d'observer les raies des protubérances en dehors des éclipses et d'y trouver une méthode pour l'étude de ces corps.

"Ces premières observations montraient déjà que les coïncidences des raies C et F étaient bien réelles, et dès lors que l'hydrogène formait en effet la base de ces matières circumsolaires. Elles établissaient en outre la rapidité des changements que ces corps éprouvent, changements qui ne pouvaient être que pressentis pendant les si courtes observations des éclipses.

"Les jours suivants, je mis à profit toutes les occasions que pouvait m'offrir l'état du ciel pour appliquer la nouvelle méthode et la perfectionner, autant du moins que le permettaient les instruments, qui n'avaient pas été construits à ce point de vue tout nouveau.

"En suivant avec beaucoup d'attention les lignes protubérantielles, j'ai quelquefois observé qu'elles pénètrent dans les lignes obscures du spectre solaire, accusant ainsi un prolongement de la protubérance sur le globe solaire lui-même. Ce résultat était facile à prévoir, mais l'interposition de la Lune en eût toujours rendu la constatation impossible pendant les éclipses.

"Je rapporterai encore ici une observation faite le 4 septembre par un temps favorable, et qui montra avec quelle rapidité les protubérances se déforment et se déplacent.

"A 9^h 50^m l'exploration du Soleil indiquait un amas de matière protubérantielle dans la partie inférieure du disque. Pour en déterminer la figure, je me servis d'une méthode qu'on pourrait appeler chronométrique, parce que le temps y intervient comme élément de mesure.

"Dans cette méthode on place la lunette dans une position fixe, choisie de manière que, par l'effet du mouvement diurne, toutes les parties de la région à explorer viennent successivement se placer devant la fente du spectroscope. On note alors pour chaque instant déterminé la longueur et la situation des lignes protubérantielles qui se produisent successivement. Le temps que le disque solaire met à traverser la fente donne la valeur de la seconde en minute d'arc. Cette donnée, combinée avec la longueur des lignes protubérantielles estimées suivant la même unité,* fournit les éléments d'une représentation graphique de la protubérance.

"L'application de cette méthode à l'étude de la région solaire dont je viens de parler indiquait une protubérance s'étendant sur une longueur d'environ 30 degrés, dont 10 degrés à l'orient du diamètre vertical, et 20 degrés à l'occident. Vers l'extrémité de la portion occidentale, un nuage considérable s'élevait à $1\frac{1}{2}$ minute du globe solaire. Ce nuage long de plus de 2 minutes, large de 1 minute, s'étendait parallèlement au limbe. Une heure après (10^h

* "Cette estimation s'obtient d'une manière facile en plaçant sur la fente du spectroscope deux fils dont l'écartement, réglé sur le foyer de la lunette collectrice, représente un nombre déterminé de minutes d'arc."

50^m), un nouveau tracé montra que le nuage s'était élevé rapidement, prenant la forme globulaire. Mais les mouvements devinrent bientôt plus rapides encore, car dix minutes après, c'est-à-dire a 11 heures, le globe s'était énormément allongé dans le sens normal au limbe solaire ou perpendiculaire à la première direction. Un petit amas de matière s'en était détaché à la partie inférieure et se trouvait suspendu entre le Soleil et le nuage principal. Le temps, qui se couvrit, ne me permet pas de poursuivre davantage.

" Resumons ces observations.

" Considérée d'abord dans son principe, la nouvelle méthode repose sur la différence des propriétés spectrales de la lumière des protubérances et de la photosphère. La lumière photosphérique, émanée de particules solides ou liquides incandescentes, est incomparablement plus puissante que celle des protubérances due à un rayonnement gazeux. Aussi a-t-il été jusqu'ici à-peu-près impossible d'apercevoir les protubérances en dehors des éclipses. Mais on peut renverser les termes de la question en s'adressant à l'analyse spectrale. En effet, la lumière solaire se distribue par l'analyse dans toute l'étendue du spectre et, par là, s'affaiblit beaucoup. Les protubérances, au contraire, ne fournissent qu'un petit nombre de faisceaux dont l'intensité reste très-comparable aux rayons solaires correspondants. C'est ainsi que les raies protubérantielles sont perçues très-facilement dans un champ spectral, sous le spectre solaire, tandis que les images directes des protubérances sont comme écrasées par la lumière éblouissante de la photosphère.

" Une circonstance fort heureuse pour la nouvelle méthode vient s'ajouter à ces données favorables. En effet, les raies lumineuses des protubérances correspondent à des raies obscures du spectre solaire. Il en résulte que non-seulement on les aperçoit plus facilement dans le champ spectral sur les bords du spectre solaire, mais qu'il est même possible de les voir dans l'intérieur de ce spectre et, par conséquent, de suivre la trace des protubérances sur le globe solaire même.

" Au point de vue de la détermination de l'espèce chimique, les procédés suivis pendant les éclipses totales comportaient toujours quelque incertitude: en l'absence de la lumière solaire, on était obligé de recourir à l'intermédiaire des échelles pour fixer la position des raies des protubérances. La nouvelle méthode permet de comparer directement les raies protubérantielles aux raies solaires. Les identifications sont alors absolument certaines.

" Au point de vue des résultats obtenus pendant la courte période où elle a été appliquée, la méthode spectro-protubérantielle a permis de constater:—

" 1°. Que les protubérances lumineuses observées pendant les éclipses totales appartiennent incontestablement aux régions circumsolaires;

" 2°. Que ces corps sont formés d'hydrogène incandescent, et que ce gaz y prédomine s'il n'en forme la composition exclusive;

" 3°. Que ces corps circumsolaires sont le siége de mouvements dont aucun phénomène terrestre ne peut donner une idée; des

amas de matière dont le volume est plusieurs centaines de fois plus grand que celui de la Terre, se déplaçant et changeant complètement de forme dans l'espace de quelques minutes.

"Tels sont les principaux résultats obtenus. J'espère que malgré l'état de ma vue, fatiguée par mes longues études sur la lumière, je pourrai continuer ces travaux. J'aurai l'honneur de soumettre les résultats au Bureau des Longitudes.

"J'ajouterai en terminant que j'ai eu l'occasion de continuer aussi mes études sur le spectre de la vapeur d'eau. Le climat de l'Inde, très-humide en ce moment, est très-favorable à ces recherches. Je suis conduit à attribuer au spectre de cette vapeur une importance tous les jours plus grande, l'ensemble de mes études à Paris et ici me conduit à reconnaître une action élective sur l'ensemble des radiations solaires, depuis les rayons obscurs jusqu'aux rayons ultra-violets, bien que dans le violet l'action élective soit beaucoup plus difficile à constater. Ces études formeront l'objet d'une communication séparée."

Southern Survey.

It is with great pleasure that the Council bring before the Society the following report of Mr. Ellery's progress in this important work.

Progress Report of the Melbourne portion of the Southern Survey.

"The zone observations for the portion of the Survey allotted to the Melbourne Observatory were commenced on the 11th April, 1866, as I have already reported.

"It was determined at the outset not to accumulate observations beyond our powers of reduction, and the rule of having one month's work reduced before commencing another has been rigidly adhered to. With the limited staff of this Observatory, and the many other duties devolving on the officers, this course does not admit of very rapid progress being made.

"The work already done comprises the observation and final reduction to the arranged epoch, of all stars down to the 9½ and many to the 10th magnitudes.

Between parallels		150°·00	and	152°·40	N.P.D.	0 h 0 m	to	24 h 0 m
,,	,,	152·40		153·20		0 10		22 10
,,	,,	153·20		154·00		11 40		15 40
,,	,,	154·00		154·40		12 10		13 30

"The number of stars observed in these zones and now reduced and tabulated is 20,471.

"The methods of observation have already been reported to the Society; our longer experience with them shows that they are well adapted to this kind of work. The two Chronographs, with

two hour hands and short conical pendulums, are admirably adapted to zone observations, and give a greater amount of accuracy and far less trouble than usually belongs to such observing. The glass reservoir pens used, however, were for a long time a great source of annoyance from their uncertainty of action, and a two-hours' zone was often spoilt by failures of the pen through plugging of the capillary bore of the nib, or from too free a flow. After many trials of different kinds of pens and pencils for recording, and of the various methods of marking the movements of the magnet armature on paper in the different forms of chronographs and telegraph instruments, I devised a pen which gives so much satisfaction in its operation, and appears so certain and reliable in its action, that I have sent a drawing and description of it as an appendix to this report.

"The mode of reading off the declinations by means of a micrometer dial and count-wheel, which indicate the position of the system of seven declination wires illuminated in a dark field, is, I am convinced, better than using a scale at the focus of the eyepiece. It admits of much more precision and relieves the observer immensely; all the reading-off from the micrometer being done by the assistant."

Spectroscopic Observations of the "Red Prominences" without an Eclipse of the Sun.

Our Fellow, Mr. Lockyer, communicated to the Royal Society, on October 11, 1866, his spectroscopic observations of solar spots, and some deductions from the appearances presented by the absorption lines. At the close of that paper Mr. Lockyer asks, "May not the spectroscope afford evidence of the existence of the red flames which total eclipses have revealed to us in the Sun's atmosphere, although they escape all other methods of observation at other times? and if so, may we not learn something from this of the recent outburst in *Corona?*" This prediction has since been most brilliantly fulfilled by the independent discoveries of M. Janssen and himself.

In January 1867, Mr. Lockyer made an application to the Government Grant Fund, administered by the Royal Society, for a more powerful spectroscope. The application was acceded to, and the construction of the instrument was intrusted to the hands of our late and much-lamented Fellow, Mr. Thomas Cooke. Increasing ill-health and engagement upon Mr. Newall's large object-glass, unfortunately, delayed its construction.

On January 7, 1868, the order was transferred to our Fellow, Mr. Browning, by whom it was finished, and placed in Mr. Lockyer's hands, October 16. At this time we were in possession of the results of the spectroscopic observations of the red flames made at the eclipse of August 18. That the red prominences consisted of luminous gas, giving a spectrum of bright

lines, was removed from the region of theory and conjecture to that of fact.

On the receipt of his spectroscope, Mr. Lockyer at once applied it to test whether it was sufficiently powerful to render the bright lines of the solar prominences visible by the comparatively greater dispersion of the surrounding light. His success was complete on the first day he gave to the work, viz. October 20th; he was enabled at once to determine that the prominences were built up of hydrogen by the absolute coincidence of two of the bright lines with the Fraunhofer's lines C and F. He was also enabled to establish a fact which may ultimately be of great importance, namely, that the bright line near Fraunhofer's D was not the line D itself, and that it did not absolutely coincide with any absorption line ordinarily present in the solar spectrum. Mr. Lockyer also was enabled to determine at once the shape and dimensions of the prominence he "felt" in his new instrument.

This discovery was announced to the Paris Academy by Mr. De La Rue, a few minutes after a second and more detailed communication from Mr. Lockyer had been placed in the hands of M. Delaunay, the President of that body, a letter was received by him from M. Janssen, who was then in India, announcing that he had also discovered the same method of research some time before, viz., on the day after the eclipse itself.

The number of cases of independent discoveries which have occurred in Science is most remarkable. It would be almost inexplicable were it not for our knowledge of the gradual steps by which each important discovery is led up to, and the number of active minds which are thus directed towards every question as it ripens for solution.

It may have been that had the unfortunate delay not occurred in the completion of his spectroscope, Mr. Lockyer would have been enabled to have anticipated the spectroscopic discoveries made during the eclipse of August 18, 1868. To leave, however, this region of conjecture, we must most warmly congratulate him on the important results which he has already obtained,—results which we hope may prove but an earnest of yet more important observations to follow.

Measures of ζ Herculis.

Mr. Knott has fortunately found a double star *ζ Herculis*, in which the companion falls within the first bright ring. He has thus been enabled to obtain, for the aperture of his telescope, the radius of the first bright ring of the star. The observed value is in most satisfactory accord with its value deduced, for mean rays, from the undulatory theory of light.

Motion of Sirius in the Line of Sight.

There are three absorption bands in the spectrum of *Sirius* which correspond very closely with the three characteristic lines of luminous hydrogen. Two of these bands have been directly compared with the spectrum of luminous hydrogen. The third is too faint for accurate comparison. The presence of all three characteristic lines and the close agreement of their positions with light of the refrangibilities of luminous hydrogen render it extremely probable that this gas is present in the absorbing atmosphere of the star. Mr. Huggins has, however, found that the brightest hydrogen line, or that corresponding to the solar line F, does not, with the dispersive power at his command, fall centrically within the corresponding absorption band in the spectrum of *Sirius*. The other lines are too faint for such delicate experimental inquiries. We cannot, however, doubt, for the reasons stated, that hydrogen is really present in the absorbing atmosphere of the star.

For comparison with the spectrum of the star, Mr. Huggins has employed hydrogen under different pressures. He has, however, shown that as the pressure is increased, the breadth of the corresponding band, as seen in his instrument, is symmetrically increased. The want of coincidence of the hydrogen line and the corresponding absorption line in the spectrum of *Sirius*, is not therefore a question of pressure. The coincidence of the three magnesium lines, *b*, with the corresponding absorption bands in the Moon's spectrum, appears in Mr. Huggins' apparatus perfect. This would appear to prove that the very great difficulty of insuring a similar refraction through the prisms for the beam from the near terrestrial light and the distant object whose spectrum is under examination, has been successfully overcome.

The want of absolute coincidence of the hydrogen line and the centre of the absorption band in the spectrum of *Sirius*, has been attributed by Mr. Huggins to a change in the refrangibility, of the light arising from the relative radial motions of the Earth and the star. Mr. Huggins' measures have assigned to *Sirius* a velocity of 29·4 miles a second receding in the direction of the line of sight.

Observations of the Spectra of Southern Nebulæ.

Lieut. John Herschel has successfully applied the instruments placed in his hand by the Royal Society for the observation of the Solar Eclipse of August last to an examination of the spectra of the Southern Nebulæ. It is interesting to find that the objects examined by him give, in some cases, a continuous spectrum, and in others a spectrum of one or more of the same bright lines which are seen in the Nebulæ which had been observed in England.

In the Great Nebula in *Orion* he has detected, in addition to the three lines, a fourth very faint line, more refrangible than F, and probably in the same position as the fourth line seen by Mr. Huggins in 18 H, IV. It is probable that this line may coincide with a line of hydrogen. Lieut. Herschel has also detected a faint continuous spectrum. Lord Rosse and Prof. Winlock have made similar observations, and suspect in addition the presence of some other lines.

The Nebula in Orion.

Two valuable drawings of the Great Nebula in the Sword-hilt of *Orion* have been communicated to the Royal Society, and a third has been published and distributed to Astronomers by Padre Secchi. The most comprehensive of these pictures is that contributed to the Royal Society by the Earl of Rosse, together with a paper, which have been recently published in the *Phil. Trans.* vol. clviii. 1868. The representation of the Nebula is $23\frac{1}{2}$ in. × $25\frac{1}{2}$ in., and comprises about one square degree, namely, 20′ to the north and 40′ to the south of the principal star in the trapezium; and 26′ to the east and 38′ to the west of that star; the nebulous matter extending beyond the star *iota*. This very beautiful picture is the graphic summation of seven years' work, performed with admirable zeal and continuity of purpose by the late noble founder and constructor of the Birr Castle telescopes, and of his staff of assistants; and also that of the present Earl, who has completed the observations commenced by his father. During these seven years it was found necessary to devote the 6-foot and 3-foot reflectors, and occasionally an 18-in. Cassegrainian, mounted equatorially, on every available hour to the work in hand, in order to produce the picture which has been published by the Royal Society. It is printed in fac-simile of the original in such a way that black represents white, but the Council have wisely had printed for distribution a certain number of copies in white ink on a black paper, thus representing the object as in nature.

The second drawing, in which black also represents white, was presented to the Royal Society by Mr. Lassell, in April 1868; it sums up the results of much arduous work performed with his 4-foot Newtonian telescope mounted equatorially, during his sojourn in Malta, extending over a period of rather over three years. This drawing is 25 inches square; it comprises a space of 13′ 20″ to the north and 15′ to the south of the principal star in the trapezium, also 15′ to the east and 13′ 20″ to the west of that star; consequently not quite $\frac{1}{4}$ of a square degree (0·223).

Astronomers have thus at command two drawings of this object by different observers, but made with the aid of instruments comparable as to aperture, although not of precisely similar dimensions. A cursory glance impresses one with the general similarity of the appearances depicted, but a closer inspection of the two pictures renders evident a great disagreement in many points of detail, quite great enough indeed to mislead in respect to any con-

clusion which might be drawn as to changes having taken place in the configuration of the nebulous matter. This is not to be wondered at, for this object varies so considerably in its aspect not only with instruments of different apertures, but also with the same instrument under different conditions of atmosphere, that it is almost impossible to state with any degree of certainty whether any physical changes have taken place in the several parts of the Nebula during the period in which it has been carefully scrutinised. The importance to future Astronomers of having drawings which have been made at about the same epoch by well-practised observers, with the aid of competent and very similar instruments, cannot therefore be overrated; and it is to be hoped on this account that the Royal Society will publish Mr. Lassell's drawing.

Padre Secchi's picture represents a space comprised within the limits of 10′ to the north, 12′ to the south, 10′ to the east, and 12′ to the west of the principal star of the trapezium; or 0·134 square degree; it is also printed in black for white. On taking into consideration the comparatively very small aperture of the instrument employed it exhibits a great amount of detail; and will have its value in the future, more especially as presenting some such general aspect of this nebula as the valuable picture which a finder to large telescope offers of a comet to be scrutinised for minute details in its larger companion. It differs, however, as might be expected very considerably from both Lord Rosse's and Mr. Lassell's drawings.

It is to be expected that now that the Melbourne 4-foot Cassegrainian has arrived at its destination, and is being erected, another record will be made of the aspect of this vast assemblage of nebulous and stellar matter, under the peculiarly favourable circumstances which the handiness of the instrument and the advantageous position of the observing station present.

When one reflects on the vast dimensions of the Nebula of *Orion*, it is difficult to realise the probability of changes occurring to such an extent in the distribution of the nebulous matter as to be recognisable at very short intervals; it is, therefore, as a basis for comparison with observations made by Astronomers some centuries hence, that the pictures to which we have drawn attention must be regarded as of the highest value; for in these remote periods possibly real changes will have occurred which cannot be confounded with the apparent changes dependent on variations of atmospheric conditions.

The Variable Star η Argûs and its Surrounding Nebula.

The papers which Mr. Abbott has communicated to the Society on this subject appear to indicate changes in the distribution of the nebulous matter around *η Argûs* of the most rapid and astounding character.

Sir John Herschel, in the *Notice* for June, vol. xxviii., has pointed out his inability to identify any of the stars near *η Argûs*, in Mr. Abbott's drawing, and expressed the strongest wish that the point thus raised of the reality of the changes in the Nebula around *η Argûs* should be settled definitely and at once. The wish thus expressed was not likely to remain disregarded.

A drawing of the Nebula has already been presented to the Society by Lieut. Herschel. In this drawing the star *η Argûs* is represented as quite within the region of nebulous matter. Lieut. Herschel's drawing agrees far more closely with his father's drawing of 1834–7 than with either of Mr. Abbott's drawings. It is, however, desirable that the Nebula should be examined under more favourable circumstances than those at the command of Lieut. Herschel.

November Meteors.

The shower of last November assumed almost unexpected proportions. Unfavourable weather interfered to a considerable extent with its observation in England. A very considerable number of meteors were, however, observed, and the position of the radiant fixed with accuracy at the Greenwich Observatory. Observers in the south of Europe, at the Cape of Good Hope, in Australia, and on the American continent, were more fortunate. The mass of materials thus collected proves the shower to have been on a most extensive scale. The succession of large November showers for at least four successive years, would appear to prove that the arc of the orbit over which considerable condensation exists is far more extensive than was formerly supposed.

The Approaching Transits of Venus of 1874 *and* 1882.

The Society, and all interested in the advancement of our noble science, are indebted to the Astronomer Royal for an elaborate discussion of the best means for utilising the approaching Transits of *Venus* in 1874 and 1882.

The method of differences of observed durations will not be the best available for the determination of Solar Parallax in 1874, and probably also not in that of 1882.

It will thus be necessary to determine with extreme accuracy the longitudes of the different stations. This necessity calls for immediate action. The Astronomer Royal has most carefully pointed out in his paper the stations which are best adapted for the location of the observers. It is one of the many advantages which we may expect to derive incidentally from the proposed expeditions, that we shall be thus driven to determine with extreme accuracy the position of so many distant stations, which will afterwards be available as zeros of longitude.

Mr. Warren De La Rue has urged the advisability of supplementing the eye-observations by photography. He is of opin-

ion that a value of the solar parallax of considerable weight may be thus obtained. His great experience and proved skill in the deduction of accurate results from photographic registers entitle his opinion to the greatest consideration.

The Astronomer Royal has proposed that altazimuths should be employed in the determination of the longitudes of the stations. Results of very much the same value as those to be expected from photography might probably be obtained without any additional expense, or interfering in the slightest degree with any other results by simply observing throughout the transits, with those altazimuths, the position of the planet with reference to the Sun's limbs.

The Astronomer Royal's application for the necessary funds is sure to meet with that liberal consideration which the British Government has ever shown towards all well-considered schemes for the advancement of science.

Discovery of Minor Planets.

Twelve Minor Planets have been discovered during the year 1868. This is the greatest number added to the list of planets in any single year. It will be seen from the tabular statement below that the diligence and zeal of Professor Watson of Ann Arbor, Michigan, have been rewarded by the discovery of no less than six out of the twelve of these minute members of the solar system. The date of each discovery is as follows:—

Planet.	Discoverer.	Date of Discovery.
Ægle	Coggia	1868, February 17
Clotho	Tempel	,, February 17
Ianthe	C. H. F. Peters	,, April 18
(99)	Borelly	,, May 29
Hecate	Watson	,, July 11
Helena	Watson	,, August 16
Miriam	C. H. F. Peters	,, August 22
(103)	Watson	,, September 7
(104)	Watson	,, September 13
(105)	Watson	,, September 16
(106)	Watson	,, October 10
Camilla	Pogson	,, November 17

A Comet, Comet I. 1868, was discovered by Dr. Winnecke on June 13.

Brorsen's and Encke's periodical Comets have been observed at their respective oppositions.

Spectrum of Comet II. 1868.

The spectrum of this faint Comet has been examined by Mr. Huggins.

There appears a very close agreement between its spectrum and that of the vapour of carbon, when obtained by the decomposition of olefiant gas and some other compounds of carbon.

Rediscussion of the Observations of the Transit of Venus, 1769.

Our Secretary, Mr. Stone, has done an important service for Astronomy by an independent discussion of the observations of the Transit of *Venus*, 1769. Skilfully applying to the descriptions of the observers an interpretation founded on the optical phenomena which necessarily attend the transit of a small dark body over the Sun, he has shown that the observations of the different observers, so far from being discordant, are in close agreement with each other, and furnish a value of the Solar Parallax which is almost identical with the new value which results from the observations of *Mars*. A more complete account of this investigation, and of Mr. Stone's other contributions to our science, will be found in the President's statement of the reasons for the award by the Council of the Gold Medal to that gentleman.

Reference in this place should be made, however, to some other papers which Mr. Stone has presented to the Society during the present year. One of these contains an investigation of the principles on which observations, which differ considerably from the general average, should be dealt with. He has deduced therefrom for different values of the average accuracy of the observer, and with certain assumed probable errors, the limits beyond which all discordant observations should be rejected.

In another paper, from an independent determination, he has found for the Moon's mass the value—

$$\frac{\text{Moon's Mass}}{\text{Earth's Mass}} = \frac{1}{81{\cdot}36}$$

Two papers are devoted to a determination of the constant of nutation, from observations in N.P.D. of *Polaris*, *Cephei* 51, and δ *Ursæ Minoris*, and in R.A. of *Polaris*, made at Greenwich from 1851 to 1867.

Communications to the Society from February 1868 *to February* 1869.

1868.

Mar. 13. Additional Identification of Double Stars in Sir William Herschel's Catalogue. Sir J. Herschel.
Observations of Minor Planets. Dr. R. Luther.
On the Lunar Crater *Linné*. Rev. T. W. Webb.
Sur les Comètes, 1857, III. and V., and 1867, III. M. Hoek.
On the Planetary Nebula 45 $\mathrm{H}_{\odot}$ IV. *Geminorum*. Rev. H. C. Key.
Sur les Phénomènes qu'un essaim de Météores très étendu venant de l'Espace présente après son entrée dans le Système Solaire. M. Hoek.

April 8. On the Lunar Crater *Linné*. Mr. Crossley.
On some Markings seen on *Venus*. Mr. Browning.
Catalogue of Known and Suspected Binary Stars. Mr. Chambers.
On the Employment of the Table given in the *Nautical Almanac* showing the correction required on account of second differences in finding the Greenwich Time corresponding to a reduced Lunar Distance. Capt. Shadwell.
On the Lustre of *Venus*. Mr. Weston.
Description of the Zenith Telescope of the United States Survey. Mr. Davison.
On the Rejection of Discordant Observations. Mr. Stone.
The Great Nebula of *Orion*. Father Secchi.
Proposal for a New Star Atlas. Mr. Proctor.
Lunar Crater *Linné*. Capt. Noble.

May 8. Occultation of γ *Tauri*. Mr. Joynson.
Lunar Crater *Linné*. Rev. T. W. Webb.
On the Variability of η *Argûs* and the surrounding Nebula. Mr. Abbott.
Eclipses of *Jupiter's* Satellites. Mr. Tebbutt, jun.
On the Stellar Longitudes assigned by Ptolemy. Major Drayson.
On the Lunar Crater *Linné*. Mr. Prince.
Remarks on the Name of the Star ξ *Scorpii* (= Fl. 51 *Libræ*). Mr. Brothers.
On a new Driving Clock for Equatoreals. Mr. Cooke.
Ephemeris of Brorsen's Comet. Dr. Bruhns.
Questions relative to the Invention of the Achromatic Telescope. Mr. Wackerbarth.
Note on *Linné*. Mr. Birt.
Catalogue of Spectra of New Stars. Father Secchi.

List of Stars to be Occulted about the time of the Great Eclipse, August, 1868. M. Ragonatha Chary.

On a Persistent Marking on *Jupiter*. Mr. Browning.

June 12. On the Variable Star *η Argûs* and the surrounding Nebula. Sir J. Herschel.

Observations of the Lunar Crater IV. A. *α* 17 IV. A. 339. Mr. Birt.

Determination of the Constant of Nutation from the Observations in N.P.D. of *Polaris*, *Cephei* 51 and *δ Ursæ Minoris*, made with the Greenwich Transit Circle, 1851 to 1865. Mr. Stone.

Nov. 13. On the Nebular Hypothesis and the Approximate Commensurability of the Planetary Periods. Mr. Kirkwood.

Re-discussion of the Observations of the Transit of *Venus*, 1769. Mr. Stone.

Observations of the Total Eclipse of August 18, 1868. Mr. Reed.

Ditto ditto Mr. Tebbutt, jun.

Observations of the Transit of *Mercury*, November 4, 1868. Prof. Chevallier.

Ditto ditto Mr. G. Williams.

On the Discovery of the Variable Star T *Coronæ*. Mr. Barker.

Description of an Automatic Transit Instrument. Mr. Kincaid.

Occultations observed at Durham. Prof. Chevallier.

On the Early History of the Achromatic Telescope. Mr. Chambers.

Transit of *Mercury*. Mr. Prince.

Ditto ditto Prof. C. P. Smyth.

Description of Drawings of *Mars*. Mr. Joynson.

Occultations of Stars of *Jupiter's* Satellites. Mr. Joynson.

Heliographical Elements of Sun-spots, August 18, 1868. Mr. Loewy.

Transit of *Mercury*. Mr. Lassell.

Field Notes of Zenith Telescope. Mr. Davidson.

On the Appearance of *Mercury* at its Transit, Nov. 5, 1868. Mr. Huggins.

On a possible Method of Viewing the Red Flames without an Eclipse. Mr. Huggins.

On the Lunar Crater *Linné*. Mr. Birt.

Letter to Rev. C. Pritchard. Sir J. Herschel.

Observations at Greenwich of the Egress of the Planet *Mercury* from the Sun's Disk, Nov. 5, 1868. The Astronomer Royal.

On a proposed Form of Spirit Level. Major Tennant.

Remarks on Mr. Stone's Paper on the Transit of *Venus*, 1769. Mr. Newcomb.

Reply to on Mr. Newcomb's Remarks on his Paper on the Transit of *Venus*, 1769. Mr. Stone.
Some Remarks and Suggestions arising from the Observations of the Transit of *Mercury*, 1868, Nov. 4. Mr. Stone.
Determination of the Constant of Nutation from Right Ascension Observations of *Polaris*. Mr. Stone.
On Aboul Hassan's Catalogue of Stars. Mr. Stone.
The anticipated Weather of 1869. Mr. Best.
On the Cause of the Difference of Time between the Mornings and the Evenings. Mr. Best.
Transit of *Mercury*. Mr. Penrose.
Ditto ditto Capt. Noble.
Ditto ditto (Photographs). Rev. Dr. Selwyn.
Reports on Solar Eclipse, Aug. 1868. Mr. Smith.
Note on his Catalogue of Binary Stars. Mr. Chambers.
Description of a new Chronograph Pen. Mr. Ellery.
Transit of *Mercury*. Mr. Buckingham.
Dec. 11. Meteors of November 1868. Mr. Kirkwood.
Measures of ζ *Herculis*. Mr. Knott.
Transit of *Mercury*. Mr. Knott.
Ditto ditto Mr. Browning.
Further Paper on an Automatic Transit Instrument. Mr. Kincaid.
Elements of newly discovered Asteroids. Mr. Watson.
Observations of the Solar Eclipse, Aug. 1868. M. Cheetry.
Ditto ditto ditto Maj. Tennant.
On a Defective Vision. Major Tennant.
Ephemeris for Observations of the Physical Features of the Planet *Mars* during the Opposition of 1869. Mr. Marth.
Observations of the Meteoric Shower of Nov. 13–14, 1868. Prof. Grant.
Preparations for Observing the Transits of *Venus*, 1874, 1882. The Astronomer Royal.
On the Observations of the Transits of *Venus* by Photography. Mr. De La Rue.
Observations of Meteors, 1868, Nov. 14. Admiral Sir E. Belcher.
1869. Transit of *Mercury*. Mr. Talmage.
Jan. 8. On the Physical Constitution of the Sun. Commander Ashe.
Comparison of Sun-spot Observations made in Dessau and Kew Observatory. Messrs. De La Rue, Stewart, and Loewy.
On the Relation of the Luminous Prominences to the Faculæ of the Sun. Mr. Brayley.
Transit of *Mercury*. Mr. Todd.
Description of the Great Nebula round η *Argûs*. Sir J. Herschel.

Note on Mr. Huggins' Paper, "On a Possible Method of Viewing the Red Flames without an Eclipse." Mr. Lockyer.
Meteors of Dec. 11, 1868. Mr. Finlayson.
Letter to Admiral Manners. Sir J. Herschel.

List of Public Institutions and of Persons who have contributed to the Society's Library, &c. since the last Anniversary.

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The Lords Commissioners of the Admiralty.
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American Academy of Arts and Sciences.
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American Academy of Natural Sciences.
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ADDRESS

Delivered by the President, Admiral Manners, on Presenting the Gold Medal of the Society to Mr. E. J. Stone.

Gentlemen, — The pleasing duty now devolves upon me, as President of this Society, to give effect to the resolution which you have adopted with such cordial unanimity by presenting to Mr. Edward James Stone the usual form of testimonial, which, in accordance with the bye-laws, is awarded annually by the Society as a recognition on its part of special services rendered in promoting the science of Astronomy.

Mr. Stone, as many of you are aware, has for nearly nine years occupied the responsible position of First Assistant at the Royal Observatory, Greenwich. He succeeded in this post to a gentleman, a valued member of our Society, who for many years had discharged the duties of his office in a manner at once eminently honourable to himself and advantageous to the interests of the renowned Institution with which he was associated. I need scarcely inform you that I refer to the able Director of the Radcliffe Observatory, Oxford.

Educated at the University within the ancient Halls of which Newton completed his academical studies, Mr. Stone entered upon his duties at the Royal Observatory with a mind thoroughly trained in a course of instruction which was eminently adapted to the career in life he had chosen.

I have reason to believe that, during the period of his connexion with the Royal Observatory, Mr. Stone has conducted himself throughout in such a manner as to earn the unqualified approbation of the Chief of that Establishment. With this, however, we have nothing to do on the present occasion.

The Society, except under circumstances of very rare occurrence, takes no cognizance of labours, however honourable and useful, which may have been performed merely in the ordinary course of official life.

We are now met, Gentlemen, to affix the seal of our recognition to services which have been rendered to Astronomy during leisure hours exclusively, which have been prompted solely by that ardent thirst for knowledge and that irrepressible longing after truth which constitute one of the distinguishing features of our common humanity.

I shall now proceed to state to you, in as concise terms as circumstances will admit of, the grounds upon which the Council unanimously resolved that the Medal of the Society should be awarded this year to Mr. Stone.

During the last few years Mr. Stone has contributed to the Society a great number of important papers on different subjects of Astronomy, which have been published either in the *Memoirs* or in the *Monthly Notices* of the Society.

Any person who gives those papers an attentive perusal will not fail to discover that they have for their leading object the investigation of improved values of the fundamental constants of astronomy by a searching discussion of large masses of trustworthy observations.

In the prosecution of his researches Mr. Stone has availed himself chiefly of the stores of valuable observations which have accumulated at the Royal Observatory, Greenwich, more especially during the incumbency of the present illustrious Director of the Institution.

I shall commence my brief review of Mr. Stone's astronomical labours with some account of his researches on the Solar Parallax.

The ancient astronomers were absolutely unacquainted with even an approximate value of the Solar Parallax. Their observations were of too rudimentary a character to exhibit any trace of an element of such delicate minuteness. The same ignorance prevailed in modern times till towards the close of the seventeenth century, when the application of the telescope to divided instruments and the invention of methods for ascertaining the errors of adjustment of instruments placed in the meridian, resulted in effecting a complete revolution in practical astronomy.

It was then only that the results of astronomical observation

acquired such a degree of precision as to hold out any hope of detecting a change in the apparent position of the Sun, or any of the planets, depending upon the inclination of the line of vision of the object with respect to the imaginary line connecting the observer with the centre of the Earth. It is well known that in the case of the Sun the determination of such a change of apparent position by direct observations of that body is beset in practice with insurmountable difficulties. Fortunately the planets *Venus* and *Mars*, which revolve, the one immediately within, the other immediately beyond the Earth's orbit, supply the astronomer with excellent methods for attacking the problem of the Solar Parallax by an indirect course of procedure.

I shall first refer to the case of *Mars*.

The orbit of this planet, besides being very excentric, is so situated with respect to the Earth's orbit that the perihelion of the one is turned very nearly towards the aphelion of the other. The result is that, in the course of successive intervals of seven or eight synodic revolutions, the planet when at the perihelion approaches very near to the Earth, and, in consequence, occupies a position which is eminently favourable for the investigation of its parallax.

We owe to Dominique Cassini the earliest determination of the Solar Parallax by a method based upon sound principles.

By a comparison of meridian observations of *Mars* made in 1671 by Richer, at Cayenne, in South America, with corresponding observations of the planet made in Paris, he obtained $9''.5$ as the most probable value of the Solar Parallax.

This was an immense step in advance, for, in all previous investigations the Solar Parallax was estimated in minutes. Several subsequent attempts to determine the Solar Parallax were made at different times down to the middle of the last century on the occasion of the near approach of *Mars* to the Earth, but in hardly any instance was the result so good as that which Cassini originally deduced from his researches on the subject.

The method for determining the Solar Parallax to which I have just referred was now about to be supplanted for a time by a new method founded upon observations of the transits of *Venus* over the Sun's disk. The peculiar advantages of this method had been forcibly pointed out by Halley.

The transits of 1761 and 1769 were close at hand, and the astronomers of the day were so far successful in impressing the public mind with their supreme importance, that the principal Governments of Europe sent out expeditions to different parts of the world for the purpose of making accurate observations of them. The results of those expeditions are well known. The transit of 1761 was from various causes imperfectly observed. The operations for observing the transit of 1769 were, on the other hand, decidedly successful. Shortly afterwards, various results for the Solar Parallax were obtained from the observations,

fluctuating between 8″·6 and 8″·3; but, as no method of discussion by a comprehensive and systematic process had been employed by any astronomer in such investigations, the definitive result of the observations could not be said to have been determined. This object, however, was finally effected by Encke, in his treatise, "Der Venusdurchgang von 1769," published at Gotha in 1824. The celebrated German astronomer determined the Solar Parallax to be 8″·5776 as the definitive result of his researches; and this value has since been universally adopted by astronomers till within the last few years.

In 1836, Professor Henderson determined the value of the Solar Parallax by a comparison of a few observations of *Mars* made at the Cape of Good Hope in 1832, with the corresponding observations made in the northern hemisphere at Greenwich, Cambridge, and Altona.

He obtained 9″·028 as the result of his researches, but the materials of his investigation were too scanty, and the residual errors were too discordant to affect the trustworthiness of the result which Encke had already deduced from the transit of *Venus* in 1769.

At the meeting of this Society, held in May 1857, the Astronomer Royal directed the attention of the Society to the great importance of determining the Solar Parallax by means of observations of *Mars* made at the approaching oppositions of 1860 and 1862.

This may now be the proper place to state that suspicions had already begun to be entertained respecting the accuracy of the value of the Solar Parallax which Encke had deduced from the transit of *Venus* in 1769.

The earliest indication of the necessity of an alteration of the received value is to be found in a letter from Professor Hansen to the Astronomer Royal, which is published in the *Monthly Notices* for November 1854 (vol. xv.). In this letter Professor Hansen states that the coefficient of the parallactic equation in the Moon's longitude, as determined by the Greenwich Observations, necessarily implies a greater value of the Solar Parallax than that which had been deduced from the transit of *Venus*, and he adds that the Dorpat Observations led to a similar conclusion.

The results of M. Le Verrier's researches shortly afterwards indicated the necessity of a similar increase of Encke's value of the Solar Parallax. In the *Annales de l'Observatoire Impérial de Paris*, vol. iv. 1858, he has determined from observation the coefficient of the lunar inequality in the Earth's longitude, and hence obtains 8″·95 for the value of the Solar Parallax. This result he has incorporated in his Solar Tables.

In vol. vi. of the same work the researches of M. Le Verrier on the movements of *Mars* and *Venus* conduct him to a similar conclusion as regards the necessity of increasing the received value of the Solar Parallax.

It may be mentioned also that about the same time the late Mons. Foucault obtained, by an ingenious arrangement, a measure of the velocity of light which necessarily implied a diminution of the radius of the Earth's orbit.

Such, then, Gentlemen, was the state of the question of the Solar Parallax previous to the opposition of *Mars* in 1862.

The opposition of 1860 had passed without attracting any special notice, the attention of astronomers having been mainly occupied with the total eclipse of the Sun, which happened in the month of July of that year. Fortunately, on the other hand, the opposition of 1862 was well observed at several important stations both in the northern and the southern hemispheres.

The principle of the method which was generally agreed upon as best adapted for the determination of the Solar Parallax in this instance, consisted in observing with meridional instruments the differences of declination between the planet and certain comparison stars which lay in the vicinity of its apparent path. Upon the basis of a considerable portion of the materials thus formed, Mr. Stone investigated the Solar Parallax in a paper which has been published in the *Memoirs* of the Society.

I cannot do better than quote his words with reference to the advantages which the method offers for effecting the object in view: — "The peculiar advantages of the method adopted appear to be that the observations can be made with the instruments of fixed observatories by observers in the ordinary routine of their work, the results obtained are so far removed from the quantities immediately observed that no knowledge of the results expected to be obtained can influence the observers. The number of observers can be sufficiently multiplied to diminish considerably every injurious effect of personality, by taking stars properly distributed above and below, and preceding and following *Mars* the effects of errors of the refraction-correction, at least in a mean result, can be destroyed; the effects of any division errrors likely to exist uncorrected in our modern instruments can be destroyed in the same way; and lastly, the observations may be indefinitely multiplied, and a continuous approximation carried on by availing ourselves of the favourable oppositions of *Mars*."

The materials which constitute the groundwork of Mr. Stone's investigation consist of observations of *Mars* and neighbouring stars made at Greenwich, the Cape of Good Hope, and Williamstown in Victoria, during the interval included between 1862, August 25, and November 23.

The results of his researches are exhibited in a system of nine tables. The three first tables contain the reduced north polar distances of the planet as determined at the three observatories. In the fourth and fifth tables the observations of the comparison stars made at the Cape of Good Hope and Williamstown are compared with the corresponding Greenwich errors and appropriate corrections hence determined.

In the sixth table the error of the Ephemeris of the planet is investigated by the aid of the Greenwich Observations.

In the seventh table the Greenwich and Cape Observations are combined together, and the Sun's equatorial horizontal parallax computed for each separate day of observation, each result having a certain weight attached to it.

In the eighth table the Greenwich and Williamstown observations are similarly combined together, and the resulting parallaxes exhibited with their appropriate weights.

In the ninth and last table the parallax for each day of observation, with its proper weight attached to it, is computed from a combination of the Greenwich, Cape of Good Hope, and Williamstown Observations, and the definitive value of the Solar Parallax is deduced. This Mr. Stone finds to be $8''{\cdot}943$, with a probable error of $0''{\cdot}051$.

It is unnecessary for me to expatiate upon the merits of this excellent paper.

The resulting value of the Solar Parallax obtained by Mr. Stone on this occasion presented a satisfactory agreement with the values of the same element which had been recently derived from other sources, and tended to strengthen the suspicion already entertained respecting the result which Encke had deduced from the observations of the Transits of *Venus*.

The next determination of the Solar Parallax by Mr. Stone is contained in a paper on the "Value of the Co-efficient of the Parallactic Inequality in the Moon's Longitude, determined by means of the Observations of the Moon made at Greenwich between the years 1848 and 1866."

The materials of this discussion consist of 2075 observations of the Moon.

The resulting value of the co-efficient of the parallactic equation is found to be $125''{\cdot}36$, and hence the value of the Solar Parallax is determined to be $8''{\cdot}850$.

I should mention here that Professor Hansen, in a communication to the Society which appears in vol. xxiv. of the *Monthly Notices*, had assigned $8''{\cdot}916$ as the value of the Solar Parallax derivable from his researhes on the lunar theory.

In 1864 Mr. Powalky subjected the observations of the transits of *Venus* to a fresh discussion, and determined the Solar Parallax to be $8''{\cdot}832$.

This discussion, which is evidently the result of very much labour, is based upon more accurate determinations of longitude than those available in Encke's time.

The rejection of many observations at the more important stations for reasons which do not appear to be warranted by any legitimate principles, and the imperfect manner in which the very few durations employed are represented in the residuals detract much from the value which would otherwise attach to this result. The weight of Encke's value would scarcely be said to be affected by this discussion.

That value still continued to put a veto on any acceptance of the values which resulted from the other methods which had applied to the determination of the Solar Parallax.

Mr. Stone's rediscussion of the Transit of *Venus* of 1769 is published in the Supplementary number of the twenty-eighth volume of the *Monthly Notices*. The materials of his researches consist of ten complete observations of the Transit made at Wardhus, Hudson's Bay, Kola, St. Joseph in California, and Otaheite.

Incomplete observations were excluded in consequence of the uncertainty which in general existed respecting the longitudes of the several stations, and the sufficiency of the observed durations for an accurate determination of the parallax.

Mr. Stone uses both apparent and real internal contacts. Corresponding to each phase, or rather to each mean phase of apparent contact and real contact, he introduces an unknown quantity. These unknown quantities are determined with the parallax correction from the ten equations of condition. The two corrections corresponding to apparent and mean phase are not, however, independent; their difference must be equal to twice the time between the mean phase of apparent and real contacts.

The resulting value of Solar Parallax is $8''{\cdot}91$, with a probable error of about $0''{\cdot}03$.

This result presents a most satisfactory agreement with the results of recent researches on the same subject derived from other sources.

Furthermore, the differences between the observed and computed durations are reduced unequivocally within the limit of the errors of observation. Thus, for example, in the case of the observations of Father Hell at Wardhus, which proved such a stumbling-block in previous researches, the residual error is reduced to $1^{s}{\cdot}7$. In point of fact the outstanding discordance between the observed and computed duration is in every case below 6^{s}.

Now, with reference to this investigation of Mr. Stone's, I would remark that it includes every complete observation from internal contacts of the transit, and yet, notwithstanding this circumstance, all the observed durations are represented with a degree of accuracy which is, beyond all doubt, within the limit of the probable errors of observation. The author has effected this object by simple interpretation of the words of the observer, inferring from his language and from the accompanying circumstances of the case whether the phenomenon noted by him referred to an apparent contact or a real contact.

This is all the liberty that Mr. Stone has allowed himself, and even this liberty has not been available except in those cases where the observer's own words are ambiguous. He has rejected nothing.

It is true that the method adopted by Mr. Stone involves the introduction into his researches of an unknown quantity corresponding to each observed phase. This is, however, equivalent to the arbitrary selection of real contact observations which had

always been previously done. In Mr. Stone's investigation, as I have already stated, the two corrections thus introduced are not independent but subject to a necessary condition. This condition is satisfied. There could not be a stronger proof than this of the legitimacy of the method pursued by Mr. Stone, according to which he introduced into his researches apparent or real contacts indiscriminately, according as the one or the other was noted by the observer.

In his paper on this subject Mr. Stone has given a faithful citation of the original observations, by which any person may satisfy himself respecting the interpretation which the author has put upon the words employed by each observer.

I have carefully perused those records, and I feel bound to state that, taking due note of the effects of irradiation and of the distinction existing between apparent and real contacts, the interpretation put upon the words of the original by Mr. Stone appears to me to be their true and simple meaning, and to be therefore the only legitimate interpretation which they can admit of.

By this important investigation, then, Mr. Stone has earned for himself the gratitude of Astronomers of all countries. He has shown beyond all doubt that the method pursued by his illustrious countryman Halley, when fairly treated, is capable of furnishing a value of the Solar Parallax commensurate in precision with the expectations formed of it.

But this is not all. Mr. Stone, by his researches in this instance, has wiped from Astronomy a reproach, which did not indeed legitimately attach to it, but which only one of those intellectual triumphs which from time to time have adorned the annals of our science was capable of extirpating.

I would mention further that by thus showing how completely the resulting value of the Solar Parallax depends upon apparently so slight a cause as misconceptions of obvious words respecting real and apparent contacts, he has done invaluable service in preparing the minds of Astronomers for the proper observation of the approaching transits of 1874 and 1882, and saved Astronomy from the possibility of a compromising and expensive failure.

We owe to Mr. Stone an important paper on the Constant of Lunar Parallax. His investigation is founded on a comparison of north polar distances of the Moon, determined at Greenwich during the years 1856–61, with corresponding places deduced from observations made at the Cape of Good Hope.

The aggregate number of observations is 239. As it is well known that considerable personality exists in the measurement of the disks of the various bodies of the planetary system, the author adopted the expedient of discussing separately the north and south limbs of the Moon.

The results to which he was conducted by this mode of procedure fully justified the considerations by which he was guided. He ascertained, in fact, that the correction to the constant of lunar parallax resulting from observations of the two limbs was sensibly

different. By a judicious combination of the separate results, however, he obtained a definitive correction, which, when applied to the theoretical value of the constant, conducted him to a value represented by 3422″·707, with a probable error of 0″·049.

The amount of the correction deduced in this instance was small, but the necessity of its application was plainly indicated by the observations, and it presents a perfect agreement with the result of a similar investigation due to Mr. Breen which is published in vol. xxxii. of the *Memoirs of the Society*.

I have now to make a few remarks on certain researches by Mr. Stone bearing more directly upon the accurate determination of the places of the stars. I would refer in the first place to a paper by him "On the Accuracy of the Fundamental Right Ascensions of the Greenwich Seven-year Catalogue for 1860."

It is well known that during the incumbency of the present Director there have emanated from the Royal Observatory, Greenwich, three Star Catalogues of fundamental importance.

First, we have the Twelve-year Catalogue of 2156 Stars, epoch 1845; then we have the Six-year Catalogue of 1576 Stars, epoch 1850; and, finally, we have the Seven-year Catalogue of 2022 Stars, epoch 1860.

Now a consideration of these Catalogues suggests two questions which it is most desirable to elucidate. In the first place, are there any grounds for supposing that the ultimate results may be affected by systematic errors, whether arising from irregularities in the rate of the clock or in the instrumental corrections, which the methods of reduction actually pursued have been incapable of eliminating?

And, secondly, is the process of reduction and successive cataloguing such as to lead to progressive accuracy as regards the resulting star-places?

Now, with reference to these points, Mr. Stone remarks that the method employed at Greenwich for determining the mean right ascensions of the fundamental stars has a tendency to affect the results with a common error, the elimination of which may be effected by observations of the Sun at the equinoxes. But what must be especially guarded against is the introduction of systematic errors, which neither observations of the Sun nor a repetition of the observations of the stars themselves can have the slightest tendency to eradicate.

Mr. Stone's method of investigation is accordingly based upon a separation of the assumed right ascension of the stars from any systematic errors with which they might be affected in the process of reduction. With a view to this object, he selects four stars of reference situated at nearly six hours of right ascension apart from each other, γ *Pegasi*, *Pollux*, *Spica*, and α *Aquilæ*, and then assuming the mean right ascension of those stars as given in the Seven-year Catalogue with unknown corrections applied to them, he forms a system of equations involving the *relative* corrections of the mean right ascensions of every combination of the reference

stars, taken two and two, for each of the seven years upon which the Catalogue is based, the relative corrections for each pair of stars being determined by means of the intermediate fundamental stars.

Finally, by the combination of the equations for the different years, he determines the definitive value of the *relative* corrections of the mean right ascensions of the four representative stars.

The result of a comparison of the relative corrections is highly satisfactory, inasmuch as it shows clearly the absence of any systematic errors of appreciable magnitude depending upon the right ascensions of the stars. Mr. Stone shows, furthermore, in the same paper, that the outstanding relative corrections of the Seven-year and Six-year Catalogues are considerably smaller than the relative corrections of the Seven-year and Twelve-year Catalogues.

I have been compelled to advert only in very brief terms to this important paper of Mr. Stone's, but I feel assured that any person who has given attention to it cannot fail to be impressed with the ability and skill with which the author has discussed the immense mass of observations constituting the groundwork of his researches.

The subject of atmospheric refraction is one which has occupied the attention of some of the most eminent astronomers and mathematicians of Europe from the time of Cassini and Newton down to the present day. The refractions now chiefly used by astronomers are those of Bessel, which were originally published in the *Fundamenta Astronomiæ*, and afterwards in a somewhat modified form in the *Tabulæ Regiomontanæ*. The theory, as is well known, is the same in both works, the only difference being that from the zenith to 85° the refractions in Bessel's later work, the *Regiomontanæ*, exceed in a slight degree those of the *Fundamenta*.

At Greenwich it has been the practice since 1857 to employ a still further modification of Bessel's refractions. From the zenith to 82° the mean refractions are those of the *Tabulæ Regiomontanæ* unaltered; from 82° to 85°, the refractions are those of the *Tabulæ Regiomontanæ* slightly diminished; while from 85° to the horizon, the mean refractions are those of the *Fundamenta* slightly diminished also. This arrangement was the result of an elaborate investigation of refraction by Mr. Main, founded partly on observations of Greenwich Circumpolar stars, and partly also on observations of South stars common to Greenwich and the Cape of Good Hope. No astronomer could be more deeply impressed than Mr. Main was with the want of symmetry which this arrangement exhibited, and, while recommending its adoption as indispensable in the existing state of matters, he regarded it merely as a provisional expedient to be supplanted at some future time by the results of a more advanced theory.

One of the objects proposed by Mr. Stone is to show that the

refractions of the *Tabulæ Regiomontanæ* from the zenith to 85° are somewhat too great.

The materials of his investigation consist partly of observations of Greenwich Circumpolar Stars, and partly of observations of stars common to Greenwich and Melbourne. The results, in so far as the latter place is concerned, refer exclusively to the years 1863, 1864, and 1865.

First, considering the case of the Greenwich Circumpolar stars, he arranges his materials in five groups, to each of which he assigns a weight according to the number of observations. He then forms an equal number of equations of condition involving a correction to the *Tabulæ Regiomontanæ*, and a correction to the co-latitude of Greenwich, and, solving them by the method of least squares, he obtains the values of the unknown quantities.

The result of this process shows that the refractions of the *Tabulæ Regiomontanæ*, down to 85° of zenith distance, are too great by a quantity of sensible magnitude, as is seen in the very considerable reduction of the residual quantities of the equations, arising from the substitution of the numerical values of the corrections.

Now Mr. Stone shows that the result of that correction is tantamount to diminishing the mean refractions of the *Fundamenta* in the proportion of 0·99797 to 1.

But at present the refractions below 85° employed at Greenwich are those of the *Fundamenta* diminished in the proportion of 0·99848 to 1.

Mr. Stone accordingly concludes that if the mean refractions of the *Fundamenta* diminished in the proportion of 0·99797 to 1 were adopted for Greenwich, there would hence result the advantage of being able to compute the refractions from the zenith to the horizon with one set of tables.

Mr. Stone then proceeds to investigate the correction for the refractions of Melbourne by means of observations of Circumpolar stars, and finally the corrections applicable to Greenwich and Melbourne respectively, by means of the observations of stars common to both Observatories. But it would occupy too much of your time if I were to enter into any further details. I may state briefly that the author obtains for the Greenwich refractions a correction the same in sign as that which he had previously derived from his discussion of the Greenwich circumpolar stars, although a correction of rather less magnitude.

With respect to the Melbourne refractions he obtains corrections agreeing in sign with the corrections to the Greenwich refractions, but differing from them in magnitude, and also differing sensibly for North and South stars. Indeed the discordances of the Melbourne observations are so considerable that Mr. Stone is inclined to look for their origin in some physical cause, and he suggests whether they may not be attributable to the fact of the strata of the atmosphere towards the south, at Melbourne, being more loaded with moisture than the strata towards the north.

I may add that the result of Mr. Stone's refraction investigation has been adopted for use at the Royal Observatory, Greenwich, with Mr. Airy's approbation.

I have thus, Gentlemen, endeavoured to give a faint outline of this paper of Mr. Stone's. Perhaps the time may not yet have arrived for a thorough re-casting of the great subject to which it refers. But of this I feel assured, that you will all agree with me in recognising the ability and skill which the author has displayed in his researches. The residual discordances which he has so clearly pointed out may not, under existing circumstances, admit of an explanation which is satisfactory in all respects, but the tracing out such anomalies cannot fail to lead to further advances in science.

We owe to Mr. Stone two papers on the Constant of Lunar Nutation which have been recently communicated to the Society.

In the first of these he has investigated the value of the nutation constant deducible from the observations in north polar distance of *Polaris*, *Cephei* 51, *δ Ursæ Minoris*, made with the Greenwich Transit Circle between the years 1851 and 1865 inclusive.

In his second paper he has investigated the value of the same element derivable from the observations in right ascension of *Polaris*, made also with the Greenwich Transit Circle between the years 1851 and 1867.

In the first of these investigations he had a difficulty to contend with arising from the circumstance of different division errors and different values of astronomical flexure having been employed successively in the reduction of the observations throughout the period of fifteen years over which they extended. Furthermore there were used in the process of reduction nadir points determined by a combination of reflecting eye-piece results with those obtained by observations of stars by reflexion.

The first step of the author, therefore, was to investigate the numerical corrections applicable to the registered north polar distances of the three stars, in order that the results might be regarded as equivalent to having been reduced according to one uniform system. Again a still further correction was required to be applied in consequence of the nutation constant used in the reductions during the earlier part of the period having been different from that used in the latter part.

Discussing, then, the observations of each star in succession the author arranges them in yearly groups, and in this manner forms a system of fifteen equations of condition involving three unknown quantities, a correction to the assumed nutation constant, a correction to the assumed north polar distance of the star, and a quantity representing the star's proper motion.

Finally, solving these equations, he obtains a value of the nutation constant affected by a quantity representing the proper motion of the star, which he leaves in the meantime undetermined.

In his second paper, which is devoted to a discussion of the mean right ascensions of *Polaris*, Mr. Stone similarly collects the observations into yearly groups, and by means of the resulting materials forms a system of seventeen equations of condition involving as unknown quantities the correction to the nutation constant, the correction to the assumed mean right-ascension of the star, and a correction to the proper motion of the star.

Solving, then, the equations by the method of least squares, he obtains the value of the nutation constant, affected with an undetermined correction to the proper motion of the star. Finally, adopting the proper motions of *Polaris* in R.A. and N.P.D., and of *Cephei* 51, and δ *Ursæ Minoris* in N.P.D., as given by Gould in his *Standard Places of Fundamental Stars*, he determines the definitive value of the constant of nutation to be $9''\cdot134$.

This result is slightly smaller than the result of any other value of the same constant which has been derived from the researches of astronomers in the present century, with the exception of the value obtained by Lindenau.

It is to be borne in mind, however, that the observations which form the groundwork of Mr. Stone's researches were all made with the same instrument, and that, too, one of the most powerful in existence for astronomical purposes, that they were carefully cleared of every known source of instrumental error, that they were all reduced according to one uniform system, and were finally subjected to a most thorough discussion.

Under these circumstances I feel bound to consider that the result obtained by Mr. Stone for the value of the nutation constant must be regarded as definitive, in so far as it is derivable from the Greenwich Observations of the present time.

In the former of his two papers on this subject Mr. Stone remarks that the corrections to the co-latitude, as determined from the yearly means of the observations of *Polaris* above and below pole, were affected by irregularities which seemed to indicate the existence of a systematic error proceeding from some undetermined cause. Assuming that these outstanding irregularities depended on the position of the Moon's node, he investigated the effects hence arising, and, upon comparing the results with those assigned by observation, he arrives at the conclusion that there may be really some grounds for supposing that the Greenwich co-latitude is affected by a periodical change. Admitting the existence of such a period he suggests whether it may not be attributable to a yielding of the Earth's crust under the Moon's action, or rather perhaps to a systematic deformation of the Earth's atmosphere arising from the same cause.

I have deemed it proper to bring under your notice this supplement of Mr. Stone's paper because from the admirable skill with which the author has eliminated every known source of error from the co-latitude corrections the outstanding anomalies acquire a value which would not otherwise attach to them.

Anomalous irregularities affecting the co-latitude of the

Greenwich Observatory, it is well known are not new. The true cause of these irregularities will no doubt be one day thoroughly ascertained. In the meantime any investigation such as that which we owe to Mr. Stone is invaluable as constituting a clue which may lead to their discovery.

It remains for me to glance briefly at one or two of the other papers which Mr. Stone has communicated to the Society.

It is well known that the stars when seen through a good telescope exhibit disks of sensible magnitude, surrounded to some distance beyond by an alternation of dark and bright rings.

The explanation of these rings upon the principles of the undulating theory of light is due to the Astronomer Royal (*Trans. Phil. Soc. Camb.* vol v.).

It may be shown by theory that the radius of any one of those rings varies inversely as the aperture.

In the *Monthly Notices* for December 1865 there is published a short paper by Mr. Stone upon this subject.

In this communication he has given measures from theory of the relative illumination of the disk at twenty different distances from the centres. The results show that there is a rapid degradation of the light of the disk towards the first black ring.

The author accordingly draws the conclusion that it by no means follows from the theory that the angular diameter of the *visible* disk varies inversely as the radius of the aperture.

Mr. Stone has contributed several papers to the *Monthly Notices*, having for their object the elucidation of certain interesting points in Physical Astronomy. I shall here confine myself to a brief allusion to one of these, a paper on the determination of the Moon's mass, which is published in the *Monthly Notices* for Jan. 1868.

In this communication to the Society Mr. Stone has investigated independently the expressions for lunisolar precession and nutation derivable from theory, and assigning to the constants of those elements their most accredited values, he hence determines the Moon's mass to be $\frac{1}{81\cdot36}$.

In a short paper which has been published in the *Monthly Notices*, Mr. Stone has considered the very important question of the circumstances which determine the rejection of discordant observations.

Distinguishing the ordinary class of graduated errors from errors due to accidental causes, he then proceeds to investigate a formula for the rejection of discordant observations, founded upon the assumption of a definite ratio of the mass of the observations being affected with errors due to accidental causes.

No doubt the assumption is to a certain extent arbitrary, but the principle is simple, and leads to a criterion for the rejection of discordant observations the arbitrariness of which is confined within comparatively narrow limits.

I have thus, Gentlemen, endeavoured to submit to you a state-

ment of the facts which have influenced the Council in their deliberations with reference to the award of the Medal for the present year.

The President then presented the Medal to Mr. Stone, addressing him in the following terms:—

Mr. Stone, in presenting you with this Gold Medal I know that I am not only placing in your hand the most honourable testimony of your great zeal and talent which it is in the power of this Society to bestow, but I feel convinced that every astronomer will recognise the award as a just tribute offered by the Society to the eminent ability, the energy, and assiduity which have distinguished your labours for the advancement of Astronomy.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President:

Admiral R. H. Manners.

Vice-Presidents:

J. C. Adams, M.A. F.R.S., Lowndean Professor of Astronomy, Cambridge.
A. Cayley, M.A. F.R.S., Sadlerian Professor of Geometry. Cambridge.
Warren De La Rue, Ph. D. F.R.S.
Rev. Charles Pritchard, M.A. F.R.S.

Treasurer:

Samuel Charles Whitbread, Esq., F.R.S.

Secretaries:

William Huggins, Esq. F.R.S.
Edward J. Stone, Esq. M.A. F.R.S.

Foreign Secretary:

Lieut.-Col. Alexander Strange, F.R.S

Council:

G. B. Airy, M.A. F.R.S., Astronomer Royal.
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Rev. Robert Main, M.A. F.R.S., Radcliffe Observer.
Captain William Noble.
Balfour Stewart, Esq. M.A. LL.D. F.R.S.
Isaac Todhunter, Esq. M.A. F.R.S.

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